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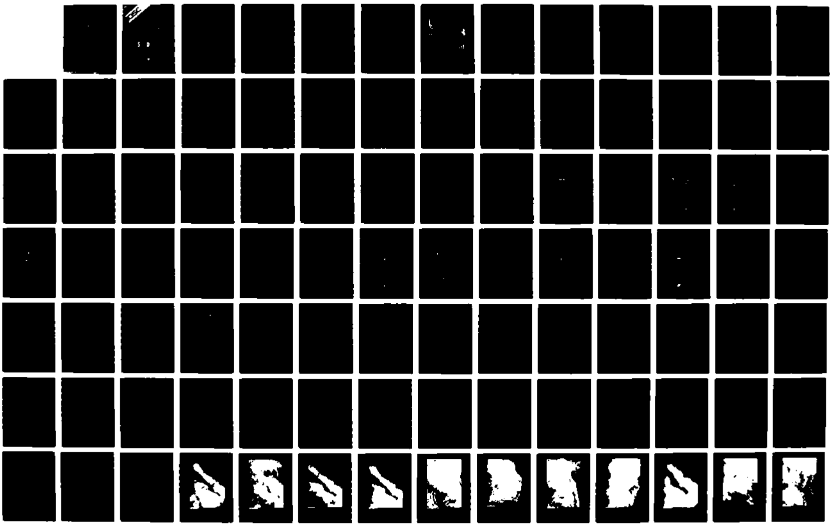

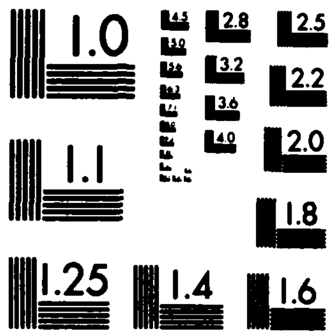

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October 1986

VARIFRONT III EXPEDITION DATA REPORT (USNS DE STEIGUER CRUISE 1202-82)

Bioluminescence, Hydrographic, Nutrient, and Satellite Data from the Gulf of California (November-December 1981)

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Suzana Potuznik
San Diego State University

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This report presents data from the expedition Varifront III, which measured stimulated planktonic bioluminescence and related physical, chemical, and biological parameters. Satellite imagery of sea surface temperature and chlorophyll was also collected. The study established a data base to develop correlates for a predictive model of the distribution and intensity of planktonic bioluminescence in surface and near-surface ocean waters.

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INTRODUCTION

During November and December 1981, the Naval Ocean Systems Center (NOSC), in cooperation with Centro de Investigaciones Cientificas y Escuela Superior de Ensenada (CICESE), Mexico, staged a multidisciplinary oceanographic survey aboard the USNS DE STEIGUER (T-AGOR 12) (Cruise 1202-82) off the west coast of Mexico and in the Gulf of California. The objective of the expedition (Varifront III) was to measure stimulated planktonic bioluminescence and a suite of related physical, chemical, and biological parameters. In conjunction with the field study, satellite imagery of sea surface temperature and chlorophyll was collected. The purpose of this study was to establish a data base to develop correlates for a predictive model of the distribution and intensity of planktonic bioluminescence in surface and near surface ocean waters.

OUTLINE OF THE EXPEDITION

The operation was divided into two parts (Leg I and Leg II). Leg I departed San Diego on 16 November, cruised south parallel to the Baja Peninsula, and arrived in Manzanillo, Mexico, on 23 November. (Data from Leg I is available from participants listed in table 1.) Leg II departed Manzanillo on 27 November and proceeded into the Gulf of California as far as 30°20'N. Measurements were made while underway and to depths of 200 m at selected stations along the northerly Gulf transect. Only underway surface measurements were made during the return transect to the south, which ended off Mazatlan on 12 December. From Mazatlan the ship returned to San Diego, arriving 16 December. The ship's cruise track and station locations are shown in figure 1. Participants of Varifront III, Legs I and II, are listed in table 1.

The field program included measurements of surface water properties made as the ship transited at a nominal speed of 10 k (underway measurements) and measurements to depths of 200 m at selected stations. Underway measurements were made of stimulated planktonic bioluminescence, sea surface temperature (using a thermistor mounted underneath the bow of the ship and a deck-mounted radiometer), chlorophyll *a* fluorescence, seawater pH, solar irradiance, and meterological information (air temperature and relative humidity). At hourly intervals, "bucket temperature," wind speed, and direction were logged. Along the southerly Gulf transect, biological samples and samples for nutrient analyses were collected hourly or more often when the underway data indicated that conditions were rapidly changing. Ten hydrographic stations were occupied within the Gulf focusing on the northern region around the islands of Angel de la Guarda and Tiburon (figure 1). Station positions are given in table 2. Generally, three casts were made at each Gulf station: (1) a conductivity, temperature, and depth (CTD)-rosette cast in which temperature and conductivity were profiled continuously as the probe was lowered to a depth of 200 m, and on the way up water samples for salinity, oxygen, and nutrient analyses were collected using 2.5-l, rosette-mounted Niskin bottles; (2) a bioluminescence cast in which a submersible bathyphotometer was used to make bioluminescence measurements to a maximum depth of 100 m and a hose attached to the exhaust of the bathyphotometer pumped seawater up to the ship's laboratory. This seawater was directed through a flow-through fluorometer for measurement of in vivo chlorophyll and/or used for collecting biological samples or samples for nutrient analyses; and (3) a productivity cast in which water samples were collected for shipboard C^{14} productivity measurements.

Biological samples collected during underway and station sampling were preserved for later taxonomic identification and enumeration and/or individual organisms were isolated and kept live for shipboard testing of luminescence (Lapota & Losee, 1984).

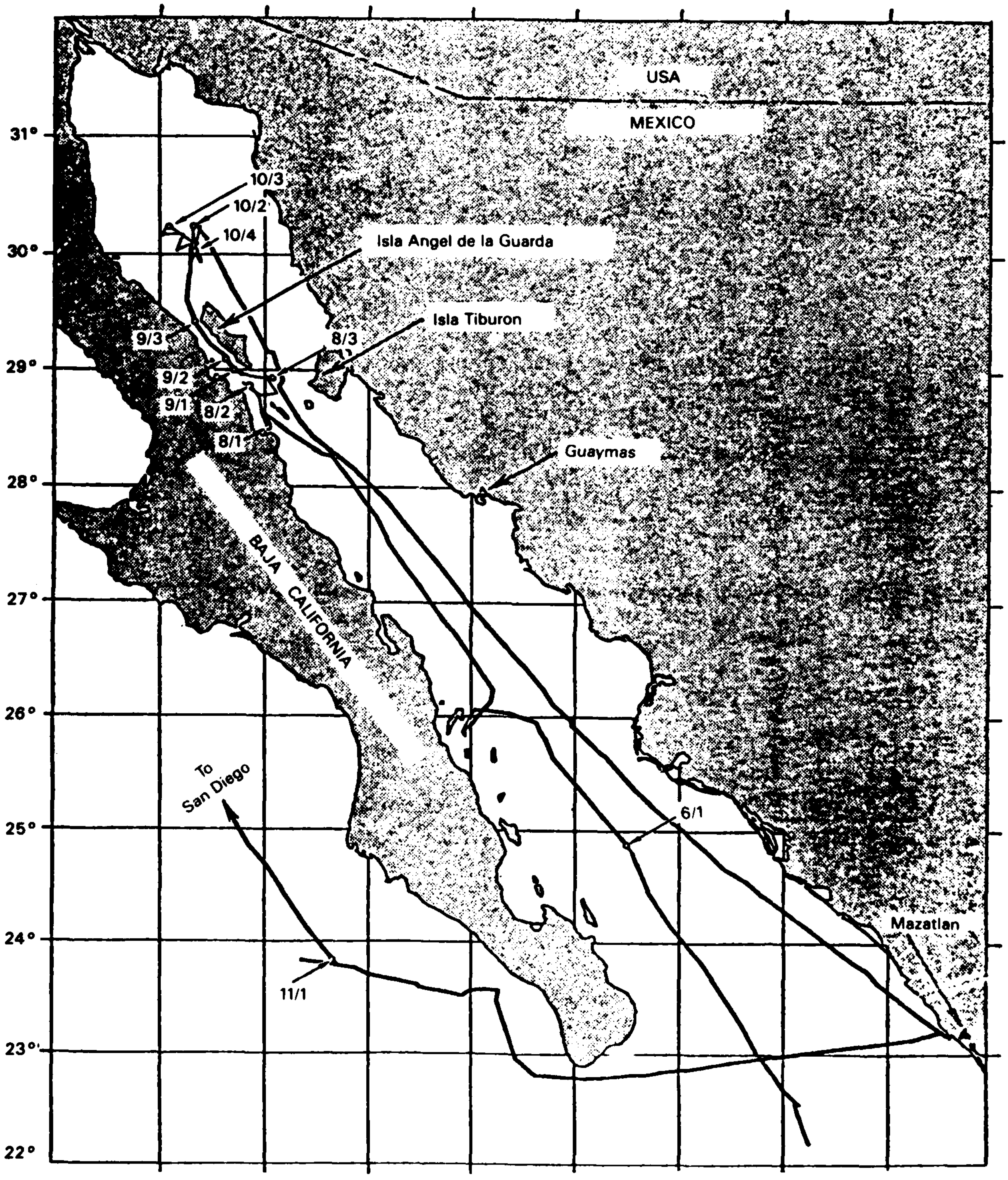


Figure 1. Map of the Gulf of California showing cruise track and station locations for Varifront III-Leg II.

Table 1. Varifront III participants.

Name	Organization	Specialty
	Leg I	
A. Zirino	NOSC	scientist in charge
D. Bower	Computer Science Corp.	data logger
W. Lund	University of Oslo	pH
E. Munoz	CICESE	
S. Potuznik	San Diego State University	oxygen
P. Seligman	NOSC	chlorophyll
R. Vidal	CICESE	
	Leg II	
S. Lieberman	NOSC	scientist in charge
L. Breaker	National Environmental Satellite Service	satellite imagery
C. Clavell	NOSC	data logger
E. Criss	NORDA, Bay St. Louis, MS	copper and radon
I. DePalma	NORDA, Bay St. Louis, MS	oxygen and hydrography
G. Gaxiola	CICESE, Ensenada, Mexico	C^{14}
D. Lapota	NOSC	bioluminescence and plankton sampling
J. Losee	NOSC	bioluminescence
G. Mitchell	University of Southern California	chlorophyll
J. Rice	NOSC	data logger and hydrography
E. Valdez	CICESE, Ensenada, Mexico	C^{14}
S. Williams	General Electric Corp., Schenectady, NY	nutrients

Table 2. Varifront III-Leg II station locations.

Station Designation	Julian Day	GMT Hour	Latitude	Longitude
6/1	334	1600	24°53.04'N	109°30.67'W
8/1	338	1550	28°31.70'N	112°58.30'W
8/2	338	2310	28°52.81'N	113°09.04'W
8/3	339	1600	28°56.93'N	112°54.26'W
9/1	339	0120	29°00.75'N	113°17.58'W
9/2	340	1600	29°05.80'N	113°22.06'W
9/3	340	0110	29°26.50'N	113°40.56'W
10/2	341	0120	30°14.68'N	113°41.02'W
10/3	342	1610	30°14.50'N	113°55.00'W
10/4	342	0120	30°01.80'N	113°40.30'W

DESCRIPTION OF THE STUDY AREA

GEOGRAPHY

The Gulf of California is a long, narrow, trough-shaped basin with a maximum depth of 1,500 fathoms at the mouth of the Gulf (23°N). The length of the Gulf is approximately 600 miles, and its width ranges from 60 miles near Isla Tiburon to 110 miles at 23°N. The Gulf is divided into a deep southern trough and a shallow northern section. The continental shelf is narrow on the Baja California side. There are numerous coves and headlands along this coast, and south of 26°N many islands jut up from the shelf. Along the Mexican coast, between 27° and 24°N, there are many low-lying, elongated bar islands beyond which lie tropical lagoons. A unique feature of the Gulf of California is that it is not separated from the adjacent ocean by a submarine ridge.

PHYSICAL OCEANOGRAPHY

Evaporation exceeds precipitation and runoff at all times in the northern basin and along the Baja California coast, and in November through May along the east coast. Heavy rainfall in the summer along the Mexican coast does not alter the net inflow of water into the Gulf. Wind-driven circulation plays an important role in the exchange of water into and out of the Gulf. Prevailing northwest winds in the winter move surface waters out of the Gulf, and the flow at depth is into the Gulf. In the summer prevailing southeast winds move surface waters into the Gulf, and flow at depth is out of the Gulf. Surface temperature gradient exhibits a strong north-south trend and a weak east-west trend. The shallow waters north of the islands vary greatly in surface temperature with the seasons, as do the tidal ranges. In the northern basin where mixing is great, temperature and salinity are generally uniform to the sill depth of the northern basin. In the southern regions, upwelling, wind speed, and direction are important in determining vertical profiles.

BIOLOGICAL OCEANOGRAPHY

Round (1967) subdivided the Gulf into three zones based on the distribution of phytoplankton species. The southernmost zone (south of Punta San Ignacio) is characterized by "old" nutrient-depleted water derived from eastern tropical Pacific water. Phytoplankton production is generally low in this

region, with the exception of areas influenced by the injection of nutrients by upwelling. The central Gulf region is characterized by strong upwelling of nutrient rich water and increased productivity. The northern Gulf is characterized as a region of low productivity and diversity with occasional intense local blooms.

METHODS

UNDERWAY SAMPLING

Seawater for underway measurements of bioluminescence and in vivo chlorophyll was drawn from the scientific sea chest through approximately 10 meters of 2.5-cm id hose up to the ship's laboratory using a self-priming Jabsco (Model 11810) pump. The sea chest penetrated the ship's hull approximately 3 m below the sea surface. Flow rate of the pumped seawater stream was measured periodically and found to be approximately 560 ml s^{-1}. This pumping system was also used for collecting underway biological samples. A second seawater pumping system, using a peristaltic pump and noncontaminating Teflon tubing, was used to draw seawater from a stainless steel conduit mounted in the forward transducer well. The conduit extended approximately 1 m below the bow of the ship. Water from this pumping system was used for pH measurements and for collecting underway nutrient samples.

VERTICAL SAMPLING

The water column was profiled using a CTD-rosette system that employed 2.5-l Niskin bottles. In addition, seawater for continuous vertical measurements was obtained from the exhaust of the submersible pump used to pull water through the bathyphotometer. Water was pumped to the surface through 100 m of 2.5-cm id hose. Once at the surface, part of the flow was directed through an on-board, flow-through fluorometer, and the remainder was used for collection of biological and chemical samples or dumped overboard.

BIOLUMINESCENCE MEASUREMENTS

Three types of bioluminescence measurements were made during the cruise: (1) underway measurements were made by drawing seawater through a 1-inch-diameter hose from the ship's sea chest up to the ship's laboratory and into a 25.5-mL viewing chamber fitted with quartz windows and bioluminescence triggered by turbulence within the viewing chamber was measured using RCA 8575 photomultiplier tubes in the photon counting mode; (2) vertical bioluminescence measurements were made using instrumentation similar in design to the on-board system, but using a submersible pump to draw seawater through a light-baffled viewing chamber. The system also employed a filter wheel that could be moved remotely so that spectral information could be obtained; and (3) individual organisms were tested for bioluminescence by separating selected individuals from plankton collections, placing them in individual filter crucibles containing filtered seawater so they could recover from the trauma of the collection procedure, and then placing the filter crucible in front of a phototube in a darkened test chamber. The seawater was then removed from the filter crucible by vacuum filtration, leaving the organism "high and dry." This provided the stimulus required to induce the organism to flash.

Signals from the photomultiplier tube (PMT) were monitored two ways: for underway and vertical bioluminescence measurements, signals from the PMT were either (1) averaged for 100-s periods using Ortec scalers, then converted to a DC signal, and recorded using a digital data logger or (2) sampled in consecutive 1-ms time bins and output as a series of pulses with a height proportional to the acquired count in the respective 1-ms time bin. These pulses were then fed into a Davidson multichannel analyzer operating in the pulse height mode. Bioluminescence from individual organisms tested in the

plankton test chamber was analyzed in the multichannel analyzer mode. For all measurements, dark-current count of the PMT was monitored routinely and subtracted from the signal count rate. Signal count rate was calibrated in terms of photons s^{-1} cc^{-1} by filling the viewing chamber with a solution of "glowing" marine bioluminescent bacteria that had previously been calibrated against a standard light source.

UNDERWAY TEMPERATURE AND CHLOROPHYLL

Sea-surface temperature was measured using an InterOcean thermistor ($\pm 0.01°C$) mounted on the end of the stainless steel conduit in the forward transducer well. Depth of the sensor was approximately 1 m below the bow of the ship. In vivo chlorophyll *a* fluorescence was measured on a portion of the exhaust from the bioluminescence viewing chamber using a Turner Designs (Model 10-005R) fluorometer. Output from the flow-through fluorometer was calibrated against chlorophyll *a* determined on acetone extracts of subsamples drawn from the hose. Seawater samples (250 mL) were filtered onto glass-fiber filters, the filters were extracted with 90-percent acetone, and the fluorescence of the extracts was measured using a Turner 111 fluorometer that had been calibrated spectrophotometrically (Strickland & Parsons, 1972).

UNDERWAY pH

In the ship's laboratory, pH was measured on a flowing stream of seawater originating from a conduit mounted in the forward transducer well, with the intake situated approximately 1 m under the bow of the ship. Determinations were made with a Corning No. 476055 combination electrode mounted in a Teflon manifold in the manner described by Zirino et al. (1982). A single electrode, in conjunction with a Corning model 103 pH meter, was used for all measurements. Initially, the electrode was calibrated in the manifold by placing appropriate buffers in a Teflon reservoir and recirculating the buffer past the electrode until a constant millivolt reading was obtained. Two buffers made to National Bureau of Standards (NBS) specifications and available commercially from Beckman Instruments (Anaheim, CA) were used. These were KH_2PO_4, 0.000869M; Na_2HPO_4, 0.03043M (pH = 7.413 at 25°C) and borax, 0.01M (pH = 9.180 at 25°C). The manifold temperature during calibration procedures and during seawater measurements was determined with a thermistor mounted in the manifold adjacent to the pH electrode. The thermistor output was read with a YSI (Yellow Springs Instrument Co.) Model 47 scanning telethermometer. pH at the in situ water temperature (bow temperature) was calculated from the mV reading of the electrode in the manifold, the electrode potentials generated in the NBS 7 and 9 buffers, calibration, and manifold temperatures, and the temperature response of the electrode according to the method described by Zirino and Lieberman (1985).

AIR TEMPERATURE AND RELATIVE HUMIDITY

Water vapor in the atmosphere can produce distortions in the satellite-inferred sea surface temperature field. Based on the assumption that water vapor in the atmospheric column is concentrated near the air-sea interface (i.e., in the marine boundary layer (MBL)) and that abrupt changes in sea surface temperature may lead to significant differences in the water vapor content in the MBL, air temperature and relative humidity were measured continuously aboard ship. Measurements were made using a thermistor and a lithium chloride hygristor (borrowed from the Meterology Department at the Naval Postgraduate School) mounted on the ship's upper deck at a height of 10 m above the ocean surface.

INFRARED RADIOMETRY

To facilitate comparisons between temperature measurements from the bow thermistor and sea surface temperature derived from satellite imagery, a portable 10.5- to 12.5-μ PRT-6 radiometer (on loan from National Aeronautics and Space Administration) was used to make measurements of sea surface temperature from approximately 4 m above the sea surface. Although the instrument was mounted on a boat boom that extended approximately 2 m off the starboard bow, we could not obtain a field of view of the ocean's surface that did not include part of the ship's wake and associated foam. As a result the radiometer record was extremely noisy. Secondly, the noise problem seemed to worsen with time, suggesting that constant exposure to the marine atmosphere may have led to some electronic deterioration of the instrument. Because of these problems, radiometer measurements were eventually suspended part way into Leg II of the operation.

UNDERWAY DATA ACQUISITION

Data from the bow thermistor fluorometer, PMT, etc., were processed using a custom-built Motorola 6800 based data logging system. Analog signals from the various sensors were subjected to a real-time analog-to-digital conversion, averaged, and stored on magnetic tape. Unless otherwise noted, all data were sampled four times a second, averaged over a 5-s period, and recorded. For a nominal ship's speed of 5 m s^{-1}, this sampling frequency corresponds spatially to a sample every 25 m.

VERTICAL TEMPERATURE AND SALINITY MEASUREMENTS

A Niel-Brown CTD system was used to determine vertical temperature and salinity profiles. For calibration purposes, water samples were collected from rosette bottle casts and salinities were determined using an Autosal. The Autosal was also used to periodically determine the salinity of surface water samples collected from the pumping system.

NUTRIENTS

Samples for dissolved phosphate, nitrate, nitrite, ammonia, and silicate were collected, quick-frozen, and stored at -10°C until the times of analysis. Samples were subsequently analyzed by the Woods Hole support group using a Technicon AutoAnalyzer. Methods used were as follows: reactive phosphate (Murphy & Riley, 1962), nitrate (Wood, Armstrong, & Richards, 1967), nitrite (Bendschmeider & Robinson, 1952), and ammonia (Soloranzo, 1969). The automated methods have been described by Grasshoff (1976).

OXYGEN

Oxygen samples were analyzed using a modified Winkler procedure (Strickland & Parsons, 1972).

PRIMARY PRODUCTIVITY

Primary productivity was determined by measuring the uptake of radioactive carbon-14 (Strickland & Parsons, 1972).

PLANKTON SAMPLING

Plankton samples were collected in two ways. The first was by periodically towing a plankton net (1-m-long, 35-µm mesh) at the surface at a speed of 2 k for 5 to 15 minutes. The other means was by pumping seawater from either the on-board system or the submersible bathyphotometer through a plankton net (35-µm mesh) for some predetermined period. Individual organisms from samples were isolated for subsequent bioluminescence testing in the laboratory test chamber or concentrated to a final volume of approximately 50 to 60 mL and preserved with 5-percent formalin. Back in the laboratory, the final sample volume of the preserved sample was accurately measured and 1-mL concentrated aliquots were withdrawn from a thoroughly mixed sample and spread onto a Sedgewick-Rafter cell for taxonomic identification and enumeration. Five thoroughly mixed, 1-mL aliquots were examined from each sample. Final plankton counts are the result of averaging five separate scans from each sample.

SATELLITE IMAGERY.

National Oceanographic and Atmospheric Administration (NOAA) 6 and NOAA 7 satellite IR imagery of the Gulf region was collected and processed by the National Earth Satellite Service (NESS), Redwood City, California. NESS also supported the study by providing satellite derived frontal positions to the ship in real time via radio facsimile. Nimbus coastal zone color scanner data and advanced very high resolution radiometer data of the study area were also collected at the Scripps Institution of Oceanography, Satellite Remote Sensing Facility. Nimbus and AVHRR data are not included in this report.

PRESENTATION OF DATA

This report contains the data collected during Varifront III-Leg II. No interpretation of the data is provided, and analysis will be presented in other publications. Results of studies undertaken by Naval Ocean Systems Center investigators have been presented at several symposia and/or prepared as manuscripts for publication in open literature (Lieberman et al, 1982; Lapota & Losee, 1982; Losee and Lapota, 1982; Zirino and Lieberman, 1982; Lapota, 1983; Lapota and Losee, 1984; Losee et al., 1985; Zirino and Lieberman, 1985; Lapota et al., 1986; Lieberman et al., 1986). Several other studies are currently in progress, and we hope this report will stimulate additional interest in the data.

All underway data collected during the expedition are keyed to time (Julian day/GMT hour; e.g., 344 0450). Table A-1 gives the ship's position as derived from satellite fixes updated at approximately hourly intervals. The cruise track plotted in figure 1 is derived from the position data listed in table A-1. The designation and location of stations along the cruise track are listed in table 2 and shown in figure 1.

Navigational data, bioluminescence, hydrographic, chemical, and biological data are presented in the appendixes.

REFERENCES

Bendschmeider, K., and Robinson, R.J. (1952). A new spectrophotometric method for the determination of nitrite in seawater. *J. Mar. Res.,* 11:87-96.

Grasshoff, K., (1976). Automated Chemical Analysis of Seawater. In: **Methods of Seawater Analysis,** K. Grasshoff, Ed., *Verlag Chem.,* Weinheim, Germany, 263-297.

Lapota, D. (1983). Bioluminescence in the marine ostracod *Cypridina americana* (Muller, 1890) off Manzanillo, Mexico (Myodocopa: Cypridininae), *Proc. Biol. Soc. Wash.,* 96, 307-308.

Lapota, D., and Losee, J.R. (1982). Observations of bioluminescence in marine plankton from the Gulf of California, *Trans. Am. Geophys. Union,* 63, 944.

Lapota, D., and Losee, J.R. (1984). Observations of Bioluminescence in Marine Plankton from the Sea of Cortez. *J. Exp. Mar. Biol. Ecol.,* 77:209-240.

Lapota D., Losee, J.R., and Geiger M.L. (1986). Bioluminescence Displays induced by Pulsed Light. *Limnol. Oceanogr.,* 31:887-889.

Lieberman, S.H., Lapota, D., Losee, J.R., and Zirino, A. (1982). Association of enhanced levels of bioluminescence with thermal boundaries in the Gulf of California. *Trans. Am. Geophy. Union,* 63, 975.

Lieberman, S.H., Lapota, D., Losee, J.R., and Zirino, A. (1986). Planktonic Bioluminescence in the Surface Waters of the Gulf of California. *Biological Oceanography,* 4:25-46.

Losee, J.R., and Lapota, D. (1982). Ultraviolet bioluminescence in the marine environment. *Trans. Am. Geoph. Union,* 63, 944.

Losee, J.R., Lapota, D., and Lieberman, S.H. (1985). Bioluminescence: A new Tool for Oceanography? In: **Mapping Strategies in Chemical Oceanography,** A Zirino, Ed., *Advances in Chemistry Series No. 209,* ACS Publications, Washington, D.C., 211-234.

Murphy, J. and Riley, J.P. (1962). A modified single solution method for the determination of phosphate in natural waters. *Anal. Chim. Acta,* 27:31-36.

Round, F.E. (1967). The phytoplankton of the Gulf of California. Part I. Its composition, distribution and contribution to the sediments, *J. Exp. Mar. Biol. Ecol.,* 76-97.

Soloranzo, L. (1969). Determination of Ammonia in Natural Waters by the Phenolhypochlorite Method. *Limnol. Oceanogr.,* 14:799-801.

Strickland, J.D.H., and Parsons, T.R. (1972). *A Practical Handbook of Seawater Analysis.* Fisheries Research Board of Canada, Ottawa, 310 pp.

Wood, E.D., Armstrong, F.A.J., and Richards, F.A. (1967). Determination of nitrate in seawater by cadmium-copper reduction to nitrite. *J. Mar Biol. Ass. U.K.,* 47:22-31.

Zirino, A., and Lieberman, S.H. (1982). The pH of Surface Waters off Baja California and the Sea of Cortez. *Trans. Am. Geophys. Union,* 63, 955.

Zirino, A., and Lieberman, S.H. (1985). pH-Temperature relationships in the Gulf of California. In: **Mapping Strategies in Chemical Oceanography,** A. Zirino, Ed., *Advances in Chemistry Series No. 209,* ACS Publications, Washington, D.C., 393-408.

APPENDIX A
NAVIGATIONAL DATA

Table A-1 gives ship's position as a function of time (Julian day/GMT hour). Positions were derived from satellite fixes updated approximately hourly.

DATE	TIME	POSITION	
333	04 04 28	22 10.08N	107 46.08W
	05 18 28	22 21.95N	107 50.25W
	05 53 39	22 27.75N	107 52.11W
	07 05 04	22 33.50N	107 54.23W
	08 40 28	22 33.10N	107 53.96W
	10 26 35	22 32.76N	107 53.16W
	10 41 11	22 32.63N	107 53.10W
	11 36 42	22 32.55N	107 52.80W
	12 25 25	22 33.28N	107 52.48W
	13 22 00	22 40.98N	108 00.31W
	14 11 18	22 48.25N	108 05.12W
	15 09 11	22 55.85N	108 11.49W
	15 39 25	22 59.86N	108 15.05W
	17 07 32	23 09.14N	108 21.53W
	17 27 32	23 12.04N	108 22.91W
	18 54 00	23 21.29N	108 28.09W
	20 29 04	23 34.72N	108 36.93W
	22 15 32	23 49.42N	108 47.26W
	23 38 28	23 58.69N	108 55.44W
	00 42 00	24 07.15N	109 02.22W
334	01 23 04	24 08.53N	109 03.63W
	02 28 00	24 14.73N	109 08.96W
	03 42 28	24 25.21N	109 16.01W
	04 27 39	24 31.57N	109 19.64W
	05 31 32	24 41.37N	109 23.96W
	06 15 14	24 47.78N	109 27.58W
	07 49 39	24 48.08N	109 28.06W
	08 00 21	24 51.00N	109 29.37W
	09 36 57	24 48.35N	109 26.99W
	11 18 07	24 47.40N	109 26.20W
	12 30 35	24 47.57N	109 27.47W
	13 03 04	24 48.70N	109 27.04W
	15 16 00	24 52.08N	109 29.98W
	16 19 18	24 53.04N	109 30.52W
	17 04 28	24 52.39N	109 30.58W
	18 04 57	24 53.04N	109 32.73W
	18 16 00	24 53.80N	109 31.86W
	19 08 00	24 55.90N	109 33.70W
335	13 00 00	25 37.00N	110 11.85W
	14 03 00	25 42.44N	110 03.28W
	15 05 00	25 45.63N	110 16.10W
	16 00 00	25 48.40N	110 17.20W
	17 00 00	25 51.04N	110 19.09W
	18 00 00	25 53.79N	110 20.93W
	19 02 28	25 57.43N	110 22.25W
	20 37 11	26 00.50N	110 25.62W
	22 23 32	26 00.29N	110 33.00W
	23 06 07	26 00.03N	110 36.31W

DATE	TIME	POSITION	
336	00 43 04	26 02.15N	110 40.89W
	02 29 32	26 03.48N	110 54.26W
	02 58 00	26 03.97N	110 58.98W
	04 35 04	25 53.85N	111 03.53W
	04 45 53	25 53.25N	111 03.48W
	06 22 00	25 48.57N	111 03.58W
	07 57 04	25 49.98N	111 04.48W
	09 44 00	25 52.47N	111 02.55W
	10 48 07	25 53.43N	111 03.78W
	11 29 18	25 54.39N	111 03.73W
	12 32 28	25 53.96N	111 04.44W
	14 19 04	25 49.34N	111 04.97W
	16 26 42	25 51.13N	111 04.46W
	18 06 14	25 52.34N	111 03.90W
	19 48 07	25 53.41N	111 03.86W
	21 34 00	25 55.22N	111 04.06W
	23 43 32	25 50.01N	111 05.51W
337	01 28 35	25 51.03N	111 04.89W
	02 35 11	25 51.76N	111 04.68W
	04 22 57	25 55.77N	110 59.09W
	05 32 00	26 02.76N	110 53.85W
	06 12 42	26 07.56N	110 48.78W
	07 18 07	26 15.41N	110 47.27W
	08 54 28	26 26.05N	110 55.57W
	10 40 35	26 38.43N	111 05.51W
	11 25 04	26 43.64N	111 09.81W
	11 41 11	26 45.49N	111 11.34W
	13 10 07	26 55.62N	111 20.92W
	13 27 04	26 57.40N	111 25.60W
	15 14 07	27 12.37N	111 32.82W
	15 55 25	27 17.58N	111 37.60W
	17 23 32	27 29.42N	111 47.36W
	17 43 32	27 32.32N	111 48.87W
	19 10 07	27 44.55N	111 55.53W
	20 45 11	27 53.03N	112 02.46W
	22 32 07	28 04.75N	112 11.71W
338	00 20 07	28 15.87N	112 21.33W
	00 44 28	28 17.95N	112 28.95W
	02 04 14	28 23.26N	112 37.80W
	02 30 35	28 24.83N	112 40.29W
	04 00 57	28 28.97N	112 46.99W
	04 41 39	28 31.87N	112 51.08W
	05 50 07	28 35.42N	112 55.87W
	06 28 28	28 37.60N	112 58.81W
	08 04 00	28 36.29N	112 58.45W
	09 50 57	28 35.03N	112 57.72W
	10 18 14	28 34.85N	112 57.73W
	11 35 46	28 33.95N	112 57.58W
	12 02 28	28 33.58N	112 57.42W
	12 35 32	28 33.05N	112 57.71W
	13 48 07	28 31.94N	112 58.32W
	14 21 32	28 31.67N	112 58.26W

DATE	TIME	POSITION	
	15 32 00	28 31.22N	112 58.30W
	16 34 42	28 30.91N	112 58.26W
	17 20 28	28 30.78N	112 57.76W
	18 20 35	28 31.87N	112 58.70W
	19 56 07	28 37.39N	113 01.37W
	21 42 00	28 46.11N	113 03.07W
	23 11 32	28 52.85N	113 08.67W
	23 51 11	28 51.84N	113 08.35W
339	00 56 35	28 52.81N	113 09.04W
	01 38 28	28 52.55N	113 08.98W
	03 38 28	28 52.21N	113 11.00W
	05 27 04	28 53.67N	113 12.45W
	05 38 28	28 53.67N	113 12.07W
	07 24 35	28 52.97N	113 11.67W
	09 01 25	28 52.57N	113 11.65W
	10 47 34	28 52.41N	113 11.87W
	11 43 39	28 50.42N	113 08.02W
	12 39 32	28 46.98N	113 01.66W
	13 29 11	28 48.02N	112 52.59W
	15 09 04	28 57.21N	112 59.85W
	16 58 00	28 55.65N	112 52.36W
	17 31 04	28 55.28N	112 52.61W
	19 18 07	28 55.41N	112 57.40W
	20 52 42	28 56.58N	113 06.21W
	22 39 39	28 57.25N	113 12.68W
	23 48 35	28 59.41N	113 16.08W
340	00 46 00	29 00.74N	113 17.65W
	01 33 11	29 00.62N	113 16.83W
	02 32 07	29 00.52N	113 16.60W
	03 16 00	29 02.42N	113 19.85W
	04 48 35	29 04.87N	113 21.61W
	05 04 07	29 05.03N	113 21.87W
	06 35 32	29 05.13N	113 21.31W
	08 11 32	29 05.09N	113 20.44W
	09 58 00	29 05.10N	113 19.45W
	11 31 32	29 04.54N	113 21.62W
	12 37 04	29 04.96N	113 23.16W
	13 16 35	29 05.20N	113 22.70W
	14 23 46	29 05.59N	113 22.19W
	14 46 07	29 05.80N	113 22.06W
	16 34 57	29 06.10N	113 20.85W
	18 28 00	29 06.60N	113 21.02W
	20 03 39	29 08.01N	113 23.57W
	21 50 00	29 10.82N	113 28.08W
	22 39 46	29 14.69N	113 32.82W
341	15 53 18	29 37.34N	113 44.85W
	16 12 00	29 39.15N	113 44.47W
	17 38 57	29 45.53N	113 44.23W
	17 59 39	29 46.32N	113 43.54W
	19 15 18	29 51.19N	113 43.15W
	19 25 46	29 52.26N	113 42.53W

DATE	TIME	POSITION	
	21 00 35	29 58.62N	113 42.37W
	22 47 39	30 05.86N	113 41.38W
	23 17 04	30 07.60N	113 41.55W
342	00 47 32	30 13.66N	113 40.97W
	01 02 14	30 14.81N	113 40.47W
	02 31 04	30 13.65N	113 40.66W
	04 18 57	30 12.55N	113 41.59W
	04 56 00	30 12.14N	113 41.76W
	06 08 42	30 11.51N	113 41.60W
	06 42 28	30 10.98N	113 41.14W
	08 18 28	30 09.19N	113 41.17W
	10 05 04	30 07.34N	113 39.42W
	11 01 04	30 06.45N	113 39.03W
	12 39 04	30 04.87N	113 38.64W
	13 59 18	30 07.91N	113 44.52W
	14 25 46	30 09.06N	113 46.50W
	15 48 57	30 14.78N	113 55.25W
	16 49 32	30 15.01N	113 55.71W
	17 37 04	30 14.53N	113 54.76W
	18 36 00	30 10.76N	113 58.34W
	20 11 32	30 10.48N	113 49.45W
	21 57 32	30 02.16N	113 50.73W
	23 54 35	30 05.47N	113 43.77W
343	01 38 42	29 54.88N	113 43.70W
	02 08 35	29 58.76N	113 41.22W
	04 05 39	29 59.01N	113 41.22W
	05 45 11	29 59.70N	113 40.60W
	07 28 35	29 59.21N	113 39.49W
	09 16 00	29 58.13N	113 37.23W
	09 53 46	29 57.75N	113 37.37W
	11 01 11	29 55.80N	113 36.71W
	11 37 32	30 00.52N	113 40.87W
	13 23 32	30 14.85N	113 37.44W
	13 33 25	30 16.09N	113 39.87W
	15 26 28	30 10.96N	113 36.54W
	16 00 14	30 08.14N	113 33.81W
	17 14 35	29 58.57N	113 28.55W
	17 46 07	29 54.20N	113 39.50W
	19 22 14	29 43.43N	113 19.40W
	19 33 18	29 41.83N	113 18.38W
	21 07 32	29 26.56N	113 08.30W
	22 46 07	29 09.08N	112 58.83W
	23 01 46	29 09.34N	112 55.83W
344	00 31 32	28 54.93N	112 49.64W
	00 49 32	28 51.64N	112 52.45W
	02 35 39	28 33.23N	112 39.44W
	03 32 28	28 25.80N	112 32.95W
	05 04 00	28 17.22N	112 20.62W
	05 21 32	28 16.85N	112 19.14W
	06 50 07	28 07.77N	112 06.42W
	08 26 57	27 55.01N	111 51.52W
	10 13 04	27 38.95N	111 36.87W

DATE	TIME	POSITION	
	10 29 32	27 36.28N	111 34.60W
	10 54 49	27 32.46N	111 31.05W
	12 14 00	27 21.01N	111 19.77W
	12 40 07	27 19.13N	111 18.11W
	14 26 42	27 06.96N	111 08.19W
	15 04 28	27 01.41N	111 03.38W
	16 52 35	26 46.58N	110 49.48W
	18 42 07	26 36.62N	110 40.24W
	20 17 32	26 26.46N	110 29.95W
	22 04 07	26 14.47N	110 17.95W
	23 24 07	26 06.44N	110 12.75W
345	01 08 35	25 57.16N	110 01.00W
	01 44 28	25 55.50N	110 01.67W
	03 08 57	25 47.56N	109 52.65W
	04 14 35	25 41.77N	109 46.17W
	04 58 00	25 38.51N	109 41.40W
	06 01 32	25 32.62N	109 36.12W
	07 38 00	25 23.92N	109 28.09W
	09 24 28	25 14.80N	109 16.96W
	11 05 04	25 06.44N	109 06.29W
	11 47 04	25 03.16N	109 01.55W
	12 50 35	24 57.78N	108 54.64W
	13 33 32	24 54.24N	108 49.99W
	14 42 00	24 48.55N	108 43.14W
	16 05 39	24 41.03N	108 35.01W
	16 30 28	24 39.25N	108 32.12W
	17 51 32	24 33.64N	108 22.34W
	19 27 39	24 25.83N	108 12.44W
	21 13 32	24 17.98N	108 01.03W
	22 16 07	24 13.66N	107 55.23W
	23 05 39	24 10.27N	107 49.84W
346	00 01 32	24 05.94N	107 43.61W
	00 52 28	24 02.65N	107 38.30W
	02 45 32	23 55.13N	107 28.73W
	03 25 11	23 52.57N	107 24.71W
	04 21 32	23 48.80N	107 19.48W
	04 34 28	23 47.75N	107 17.34W
	05 12 28	23 44.42N	107 10.69W
	06 48 35	23 37.89N	107 05.20W
	08 35 32	23 30.08N	106 54.52W
	09 57 04	23 24.26N	106 47.92W
	10 21 11	23 22.69N	106 45.91W
	10 54 42	23 20.64N	106 43.46W
	11 41 32	23 18.03N	106 39.23W
	12 40 35	23 14.51N	106 33.96W
	13 27 18	23 12.14N	106 30.12W
	14 19 32	23 09.77N	106 27.36W
	15 15 46	23 09.89N	106 26.67W
	16 08 28	23 09.42N	106 24.60W
	17 01 32	23 09.89N	106 26.70W
	18 38 14	23 08.29N	106 24.03W

DATE	TIME	POSITION	
	18 48 49	23 11.27N	106 28.45W
	20 23 39	23 07.35N	106 46.16W
	22 54 00	23 03.55N	107 14.53W
347	00 00 28	23 02.36N	107 27.34W
	00 38 35	23 01.36N	107 34.80W
	01 46 35	23 00.69N	107 41.77W
	02 22 57	22 59.81N	107 49.55W
	04 10 57	22 58.23N	108 10.01W
	04 22 49	22 58.03N	108 12.64W
	06 09 32	22 55.29N	108 32.50W
	07 46 28	22 52.41N	108 50.65W
	09 32 28	22 50.72N	109 09.82W
	10 33 39	22 49.18N	109 20.67W
	11 48 07	22 48.43N	109 34.19W
	12 18 42	22 47.91N	109 40.03W
	13 34 42	22 46.48N	109 53.89W
	13 56 35	22 46.44N	109 57.29W
	15 45 32	22 47.99N	110 18.53W
	16 12 07	22 48.30N	110 23.15W
	17 58 28	22 57.06N	110 34.84W
	19 34 35	23 11.73N	110 39.31W
	21 21 04	23 27.97N	110 45.46W
	21 44 49	23 31.97N	110 45.25W
	23 07 39	23 33.84N	110 43.28W
	23 30 35	23 34.55N	110 51.92W
348	00 54 28	23 33.63N	111 01.35W
	01 15 11	23 33.08N	111 05.97W
	02 00 35	23 33.34N	111 15.53W
	03 32 42	23 35.53N	111 31.14W
	03 48 28	23 36.72N	111 33.19W
	05 20 00	23 41.88N	112 00.21W
	06 55 46	23 45.32N	112 07.80W
	07 05 25	23 47.71N	112 08.48W
	08 43 04	23 49.88N	112 39.30W
	09 26 49	23 47.31N	112 17.58W
	10 28 42	23 47.09N	112 17.47W
	10 56 42	23 46.76N	112 17.87W
	11 10 42	23 47.00N	112 17.79W
	12 56 07	23 51.80N	112 22.15W
	14 29 39	24 03.58N	112 32.31W
	15 22 28	24 10.78N	112 37.44W
	17 09 32	24 17.13N	112 15.45W
	18 56 35	24 40.23N	112 58.27W
	20 32 00	24 52.82N	113 10.19W

DATE	TIME	POSITION	
	22 19 11	25 07.41N	113 19.46W
349	00 01 32	25 21.81N	113 30.01W
	01 38 42	25 35.26N	113 39.51W
	03 26 28	25 49.93N	113 50.96W
	04 29 32	25 58.42N	113 58.21W
	05 15 39	26 04.84N	114 02.75W
	06 16 00	26 12.95N	114 09.38W
	07 52 57	26 25.99N	114 29.54W
	09 39 04	26 40.64N	114 32.22W
	10 04 07	26 44.22N	114 34.96W
	11 50 35	24 09.21N	116 24.04W
	13 34 42	27 13.12N	114 59.16W
	14 58 57	27 24.83N	115 08.76W
	16 21 04	27 36.34N	115 17.91W
	16 47 04	27 40.00N	115 20.39W
	18 07 32	27 51.38N	115 28.71W
	19 43 32	28 05.11N	115 39.88W
	21 30 00	28 20.58N	115 49.05W
	22 58 07	28 34.96N	115 56.27W
350	00 43 04	28 51.86N	116 01.34W
	00 54 49	28 54.12N	116 02.68W
	02 40 14	29 09.98N	116 08.48W
	03 04 57	29 13.63N	116 10.60W
	03 38 14	29 18.59N	116 12.33W
	04 53 32	29 30.57N	116 16.41W
	05 25 32	29 35.72N	116 18.68W
	07 01 11	29 51.20N	116 24.17W
	07 11 18	29 53.03N	116 24.85W
	08 48 57	30 08.55N	116 30.65W
	10 34 07	30 26.07N	116 37.63W
	11 00 42	30 30.49N	116 39.45W
	12 27 04	30 45.26N	116 44.48W
	12 46 07	30 48.45N	116 45.18W
	14 34 28	31 05.91N	116 53.54W
	15 33 11	31 16.00N	116 57.50W
	16 23 25	31 24.76N	117 00.53W
	17 18 35	31 33.80N	117 03.24W
	18 56 14	31 48.98N	117 08.27W
	19 05 53	31 50.62N	117 08.80W
	20 41 32	32 04.04N	117 14.82W
	22 29 04	32 17.68N	117 19.94W

APPENDIX B
DISCRETE FLUOROMETRIC DETERMINATION

Table B-1 gives the time (Julian day/GMT hour) the sample was collected and its values in μg/L. Underway chlorophyll *a* values were calculated from in vivo chlorophyll fluorescence measurements using a calibration factor derived from the regression of the acetone extracted values reported in this table with in vivo chlorophyll fluorescence voltages.

DATE	TIME (GMT)	CHL a	PHEO-P
333	1353	0.285	0.119
333	1500	0.182	0.066
333	1600	0.277	0.090
333	1650	0.254	0.063
333	1800	0.269	0.089
333	1900	0.266	0.070
333	2000	0.225	0.077
333	2100	0.325	0.132
333	2246	0.253	0.095
334	0033	0.364	0.195
334	0100	0.867	0.504
334	0208	0.497	0.172
334	0305	0.453	0.232
334	0411	0.414	0.203
334	0511	0.292	0.205
334	1911	0.749	0.234
334	2030	1.01	0.683
334	2120	0.761	0.251
334	2126	0.660	0.174
334	2207	0.729	0.185
334	2255	0.816	0.292
335	0000	0.836	0.549
335	0200	0.893	0.295
335	0310	2.36	0.195
335	0400	2.37	0.818
335	0510	1.67	0.729
335	0606	0.785	0.290
335	0706	1.37	1.07
335	0805	0.610	0.374
335	0915	1.15	0.916
335	1001	0.827	0.452
335	1054	2.52	0.952
335	1217	1.19	0.552
335	1305	0.552	0.408
335	1606	0.80	0.40
335	1700	0.849	0.584
335	1800	0.819	0.493
335	1900	0.917	0.668
336	1200	0.716	0.484
336	1308	0.709	0.433
336	1416	0.716	0.484
337	0400	0.663	0.287
337	0500	0.477	0.215
337	0600	0.670	0.198
337	0700	0.415	0.233
337	0824	0.301	0.222
337	0911	0.372	0.206
337	1000	0.383	0.265
337	1105	0.519	0.315

DATE	TIME	CHL a	PHEO-P
337	1207	0.514	0.330
337	1319	1.41	0.505
337	1403	0.946	0.654
337	1458	0.670	0.198
337	1600	0.670	0.221
337	1659	0.611	0.235
337	1800	0.946	0.151
337	1857	1.58	0.709
337	1957	1.22	1.04
337	2300	3.47	1.65
338	0020	2.73	0.889
338	0107	2.92	0.375
338	0256	4.60	0.465
338	0330	5.46	1.05
338	0457	4.95	0.698
338	2100	8.75	1.95
338	2157	7.09	1.13
338	2257	6.38	1.02
339	1212	6.51	1.32
339	1404	4.45	0.711
339	1859	5.38	0.647
339	2004	7.64	0.39
339	2205	8.86	0.459
339	2305	8.78	0.72
340	0036	7.96	0.35
340	0359	7.16	0.223
340	2000	6.38	1.02
340	2100	8.75	0.577
340	2200	6.79	1.08
341	2058	4.41	0.71
341	2158	1.69	0.46
341	2300	2.92	1.02
342	0000	3.90	0.99
342	1959	1.52	0.24
342	2200	3.59	0.39
342	2300	2.96	0.84
343	0000	3.34	0.72
343	0030	1.82	1.12
343	0100	2.56	1.00
343	1500	0.66	0.33
343	1600	1.01	0.60
343	1700	1.09	0.54
343	1804	2.94	0.29
343	1900	4.96	1.25
343	2000	1.87	0.67
343	2100	3.15	0.41
343	2200	2.87	0.64
343	2300	3.43	0.73
344	0015	3.47	0.01
344	0100	3.78	0.06
344	0200	2.55	0.68

DATE	TIME	CHL a	PHEO-P
344	0300	4.78	0.58
344	0450	6.33	0.0
344	0600	1.43	1.25
344	0700	1.09	0.63
344	0800	1.17	0.64
344	0902	0.99	0.84
344	1300	1.43	0.59
344	1403	5.31	1.21
344	1500	1.02	0.44
344	1700	1.35	0.40
344	1800	1.58	0.53
344	1900	0.95	0.67
344	2000	1.35	0.77
344	2100	2.63	2.21
344	2200	1.30	0.53
344	2300	6.95	0.54
345	0009	1.56	0.52
345	0100	1.81	0.47
345	0208	2.52	0.68
345	0300	2.60	0.51
		16.22	0.45
345	0457	1.64	0.99
345	0600	1.20	0.58
345	0700	5.66	1.08
345	0800	4.57	1.28
345	0900	1.45	0.60
345	1102	6.21	0.08
345	1508	1.38	0.36
345	1700	0.50	0.15
345	1900	0.53	0.22
346	1900	0.39	0.06
346	2000	0.34	0.06
346	2100	0.36	0.099
346	2400	0.22	0.05
347	0100	0.24	0.04
347	0500	0.40	0.11
347	0700	0.23	0.13
347	1200	0.25	0.02
347	1440	0.27	0.04
347	1600	0.17	0.05
347	1800	0.30	0.11
347	2200	0.18	0.03
347	2400	0.16	0.04
348	2000	0.23	0.04

APPENDIX C
SALINITY OF SURFACE WATER SAMPLES

Samples in table C-1 were collected in conjunction with copper/radon samples. Water for salinity analyses was taken from the sea chest pumping system.

Table C-1. Salinity of surface water samples collected during underway transects.

Time (Julian day/GMT hour)	Salinity (°/00)
332/1830	34.309
332/2010	34.292
333/0100	34.434
333/0220	34.412
333/1630	34.698
333/1750	34.742
334/0100	35.067
334/0215	34.983
334/1815	35.264
334/2100	35.164
337/1310	35.255
337/2115	35.241
343/2300	35.49
344/0015	35.53
344/0500	35.21
344/0630	35.26
344/1230	35.24
344/1400	35.17
344/1715	35.21
344/1805	35.23
344/2247	35.15
345/0015	35.23

APPENDIX D
EXPENDABLE BATHYTHERMOGRAPHS (XBT)

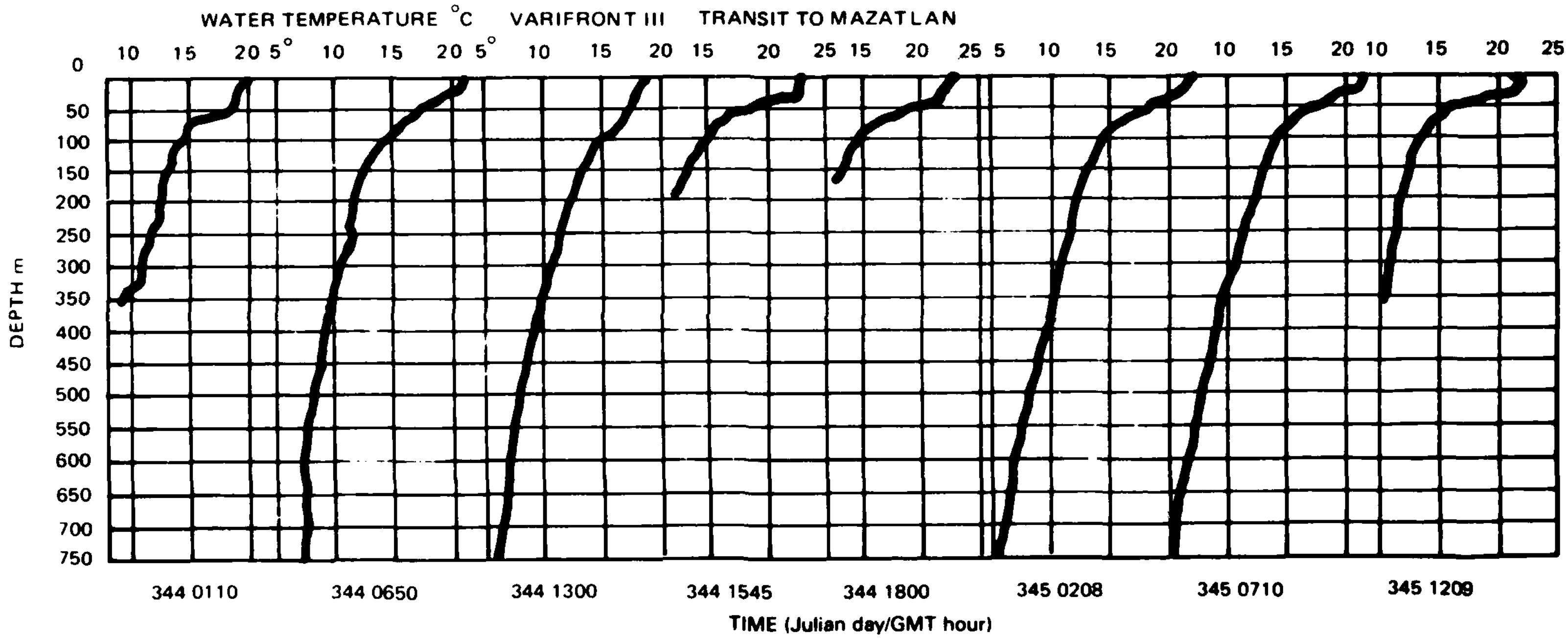


Figure D-1. Expendable bathythermographs for each trace along the southerly Gulf transect.

APPENDIX E
PLOTS OF UNDERWAY DATA

Appendix E contains plots of continuous underway measurements of sea surface temperature (from the bow thermistor), planktonic bioluminescence, in vivo chlorophyll concentrations, seawater pH, solar radiance, air temperature, and relative humidity. These are presented in figures E-1 to E-30. Details of each measurement are described in the methods section of this report. Data are plotted as raw calibrated data: an appropriate calibration factor was applied to the voltage recorded on the data logger for each sensor but the data do not reflect any other treatment. That is, the data have not been edited to remove bad or missing data or have not been averaged or filtered to remove any high frequency noise. The data are plotted at the original sampling frequency (a sample every 5 s). To facilitate comparisons between different time segments, every parameter, with the exception of pH, has been plotted on the same scale. Bioluminescence is plotted on a log scale. Units are as follows:

Parameter	Units
Water temperature (bow thermistor)	°C
Bioluminescence	photons/s/cc
Chlorophyll	μg/L
pH	pH units ($-\log(H^+)$)
Solar radiometer	einsteins/m^2/day
Air temperature	°C
Relative humidity	percent

Missing data indicate that data were not available for that time segment. Usually, data were not available because of instrumental problems with the individual sensors (this was common for air temperature and relative humidity) or, in some cases, sensors were off life for calibration, cleaning, or pump maintenance. The beginning time (Julian day/GMT hour) of each segment plotted is given below the plot of temperature in each figure.

Printouts of 5-minute averages of data plotted in this section are available upon request from the author.

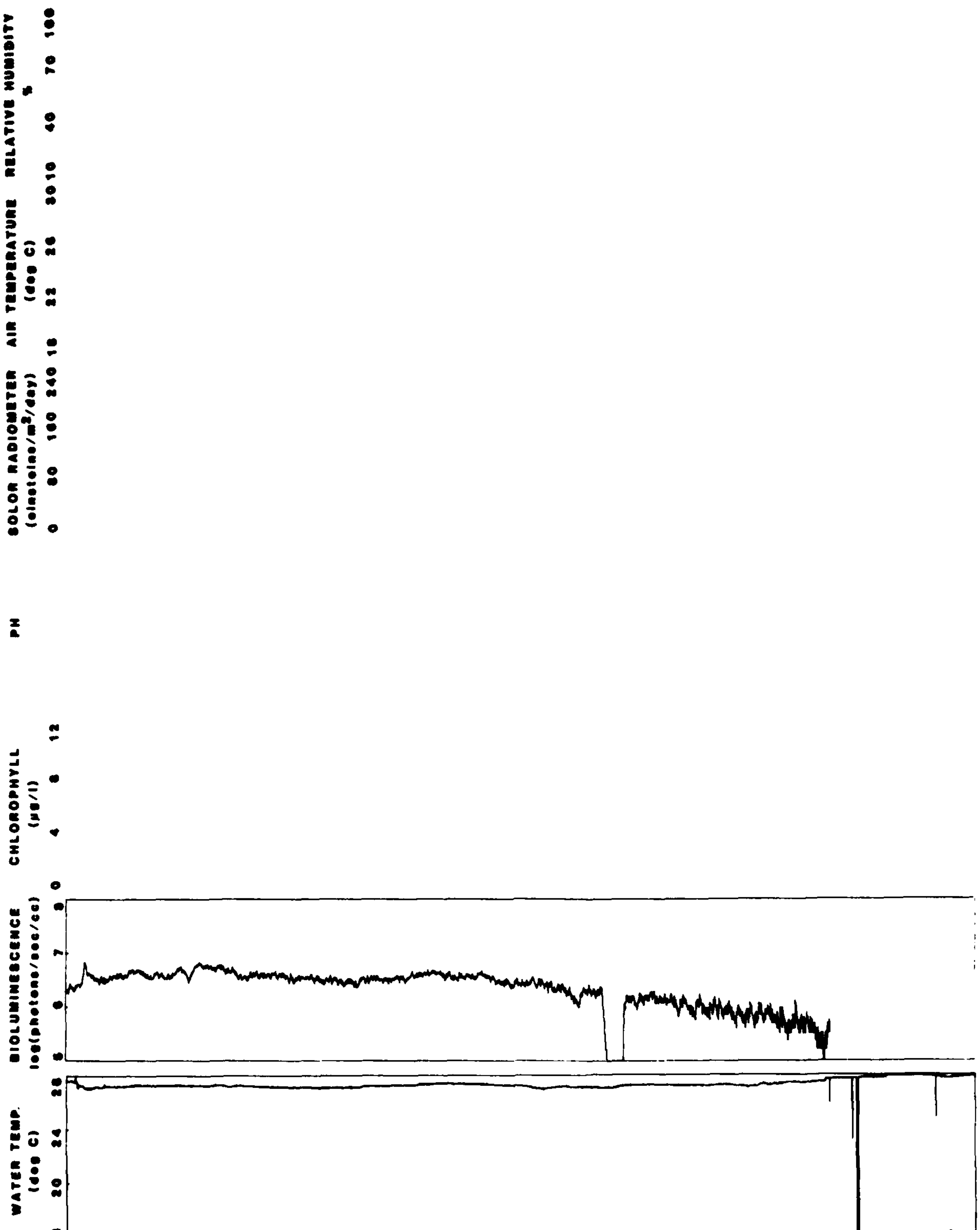

SOLOR RADIOMETER
(einsteins/m2/day)
AIR TEMPERATURE
(deg C)
RELATIVE HUMIDITY
%
PH
CHLOROPHYLL
(µg/l)
BIOLUMINESCENCE
log(photons/sec/cc)
WATER TEMP.
(deg C)
VARFRNT III CALIBRATE 332 0224
HOURS

Figure E-1.

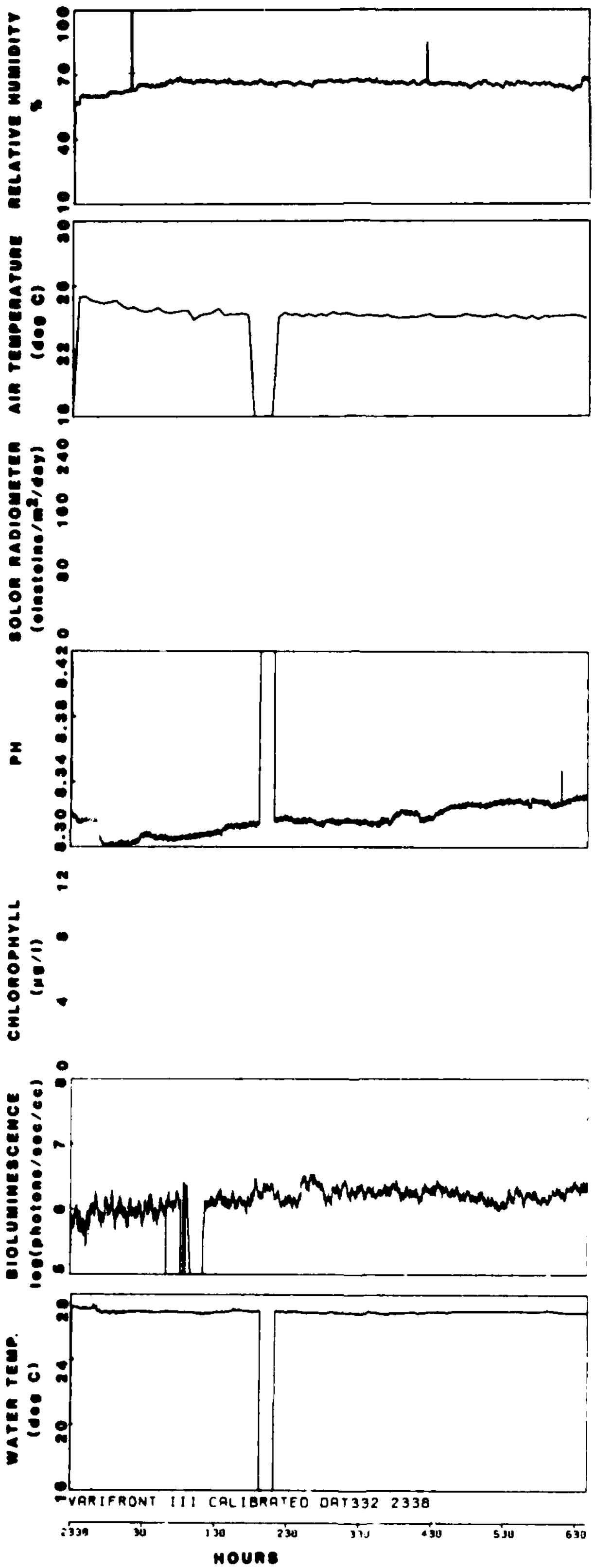

RELATIVE HUMIDITY %
AIR TEMPERATURE (deg C)
SOLOR RADIOMETER (einsteins/m2/day)
PH
CHLOROPHYLL (µg/l)
BIOLUMINESCENCE log(photons/sec/cc)
WATER TEMP. (deg C)
VARIFRONT III CALIBRATED DAT332 2338
HOURS

Figure E-2.

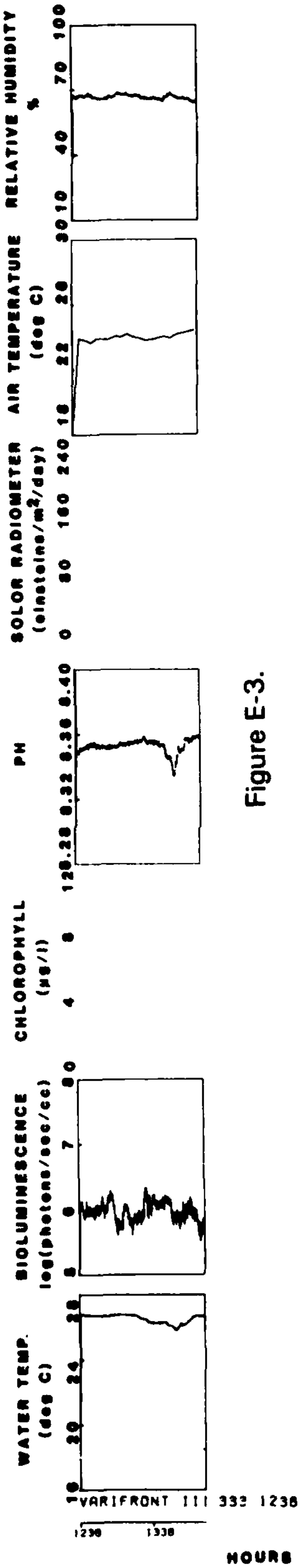

WATER TEMP. (deg C)
BIOLUMINESCENCE log(photons/sec/cc)
CHLOROPHYLL (µg/l)
PH
SOLOR RADIOMETER (einsteins/m2/day)
AIR TEMPERATURE (deg C)
RELATIVE HUMIDITY %
VARIFRONT III 333 1238
HOURS

Figure E-3.

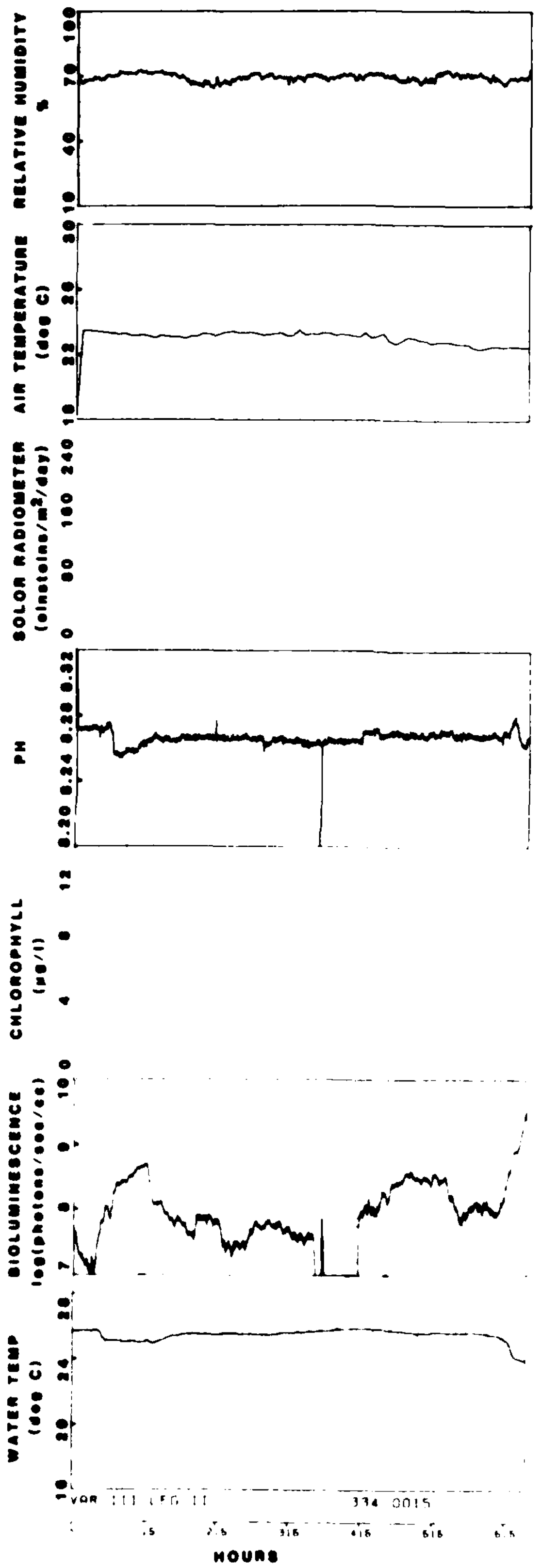

RELATIVE HUMIDITY
%
AIR TEMPERATURE
(deg C)
SOLOR RADIOMETER
(einsteins/m2/day)
PH
CHLOROPHYLL
BIOLUMINESCENCE
log(photons/sec/cc)
WATER TEMP
(deg C)
HOURS

Figure E-4.

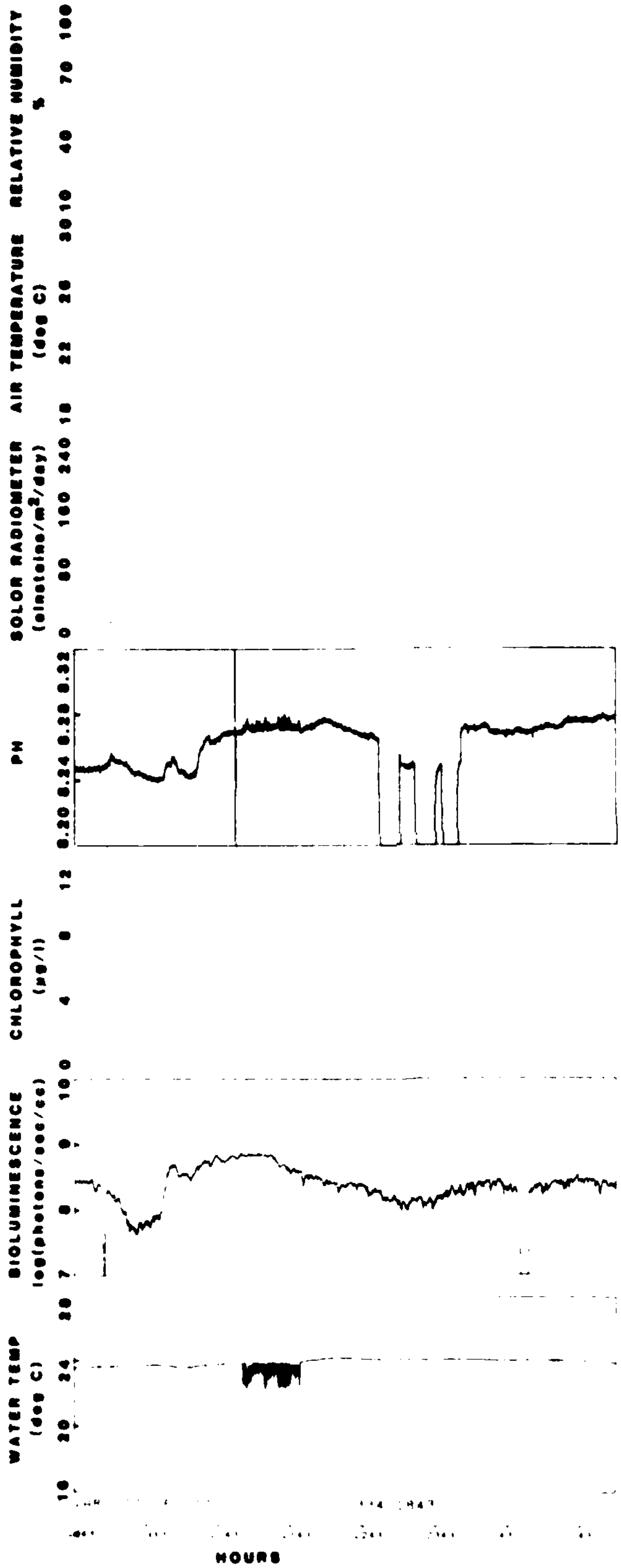

WATER TEMP
(deg C)
BIOLUMINESCENCE
log(photons/sec/cc)
CHLOROPHYLL
(µg/l)
PH
SOLOR RADIOMETER
(einsteins/m²/day)
AIR TEMPERATURE
(deg C)
RELATIVE HUMIDITY
%
HOURS

Figure E-5.

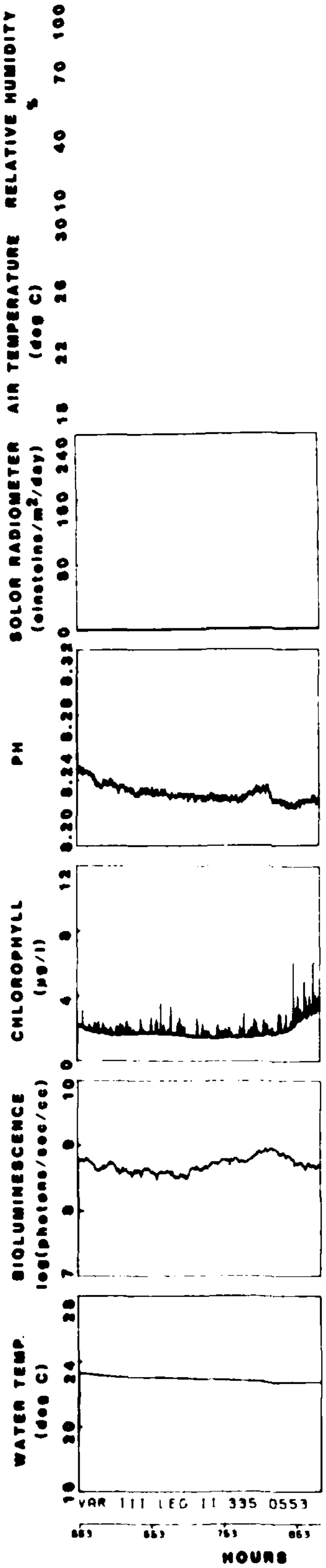
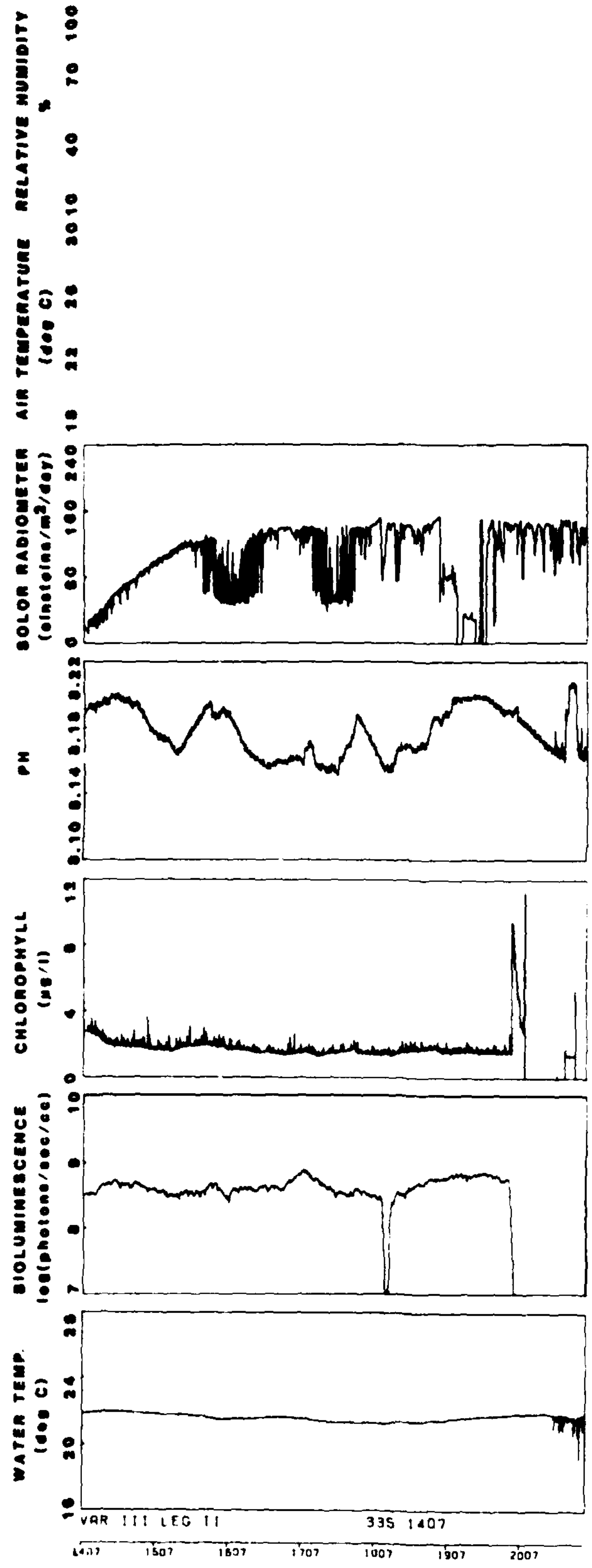

WATER TEMP.
(deg C)
BIOLUMINESCENCE
log(photons/sec/cc)
CHLOROPHYLL
(µg/l)
PH
SOLOR RADIOMETER
(einsteins/m²/day)
AIR TEMPERATURE
(deg C)
RELATIVE HUMIDITY
%
VAR III LEG II 335 0553
HOURS

Figure E-6.



RELATIVE HUMIDITY
%
AIR TEMPERATURE
(deg C)
SOLOR RADIOMETER
(einsteins/m²/day)
PH
CHLOROPHYLL
(µg/l)
BIOLUMINESCENCE
log(photons/sec/cc)
WATER TEMP.
(deg C)
VAR III LEG II
33S 1407
HOURS

Figure E-7.

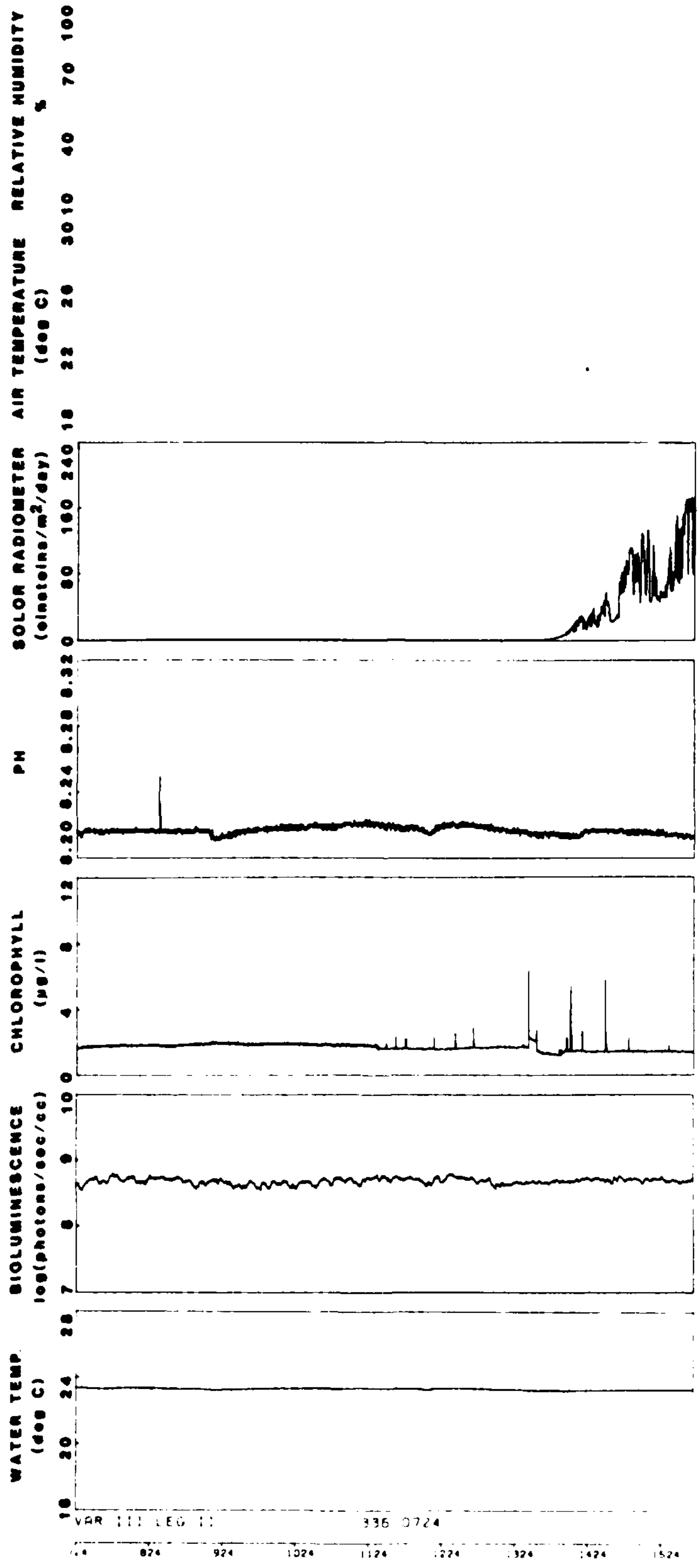

WATER TEMP. (deg C)
BIOLUMINESCENCE log(photons/sec/cc)
CHLOROPHYLL (µg/l)
PH
SOLOR RADIOMETER (einsteins/m2/day)
AIR TEMPERATURE (deg C)
RELATIVE HUMIDITY %
HOURS

Figure E-8.

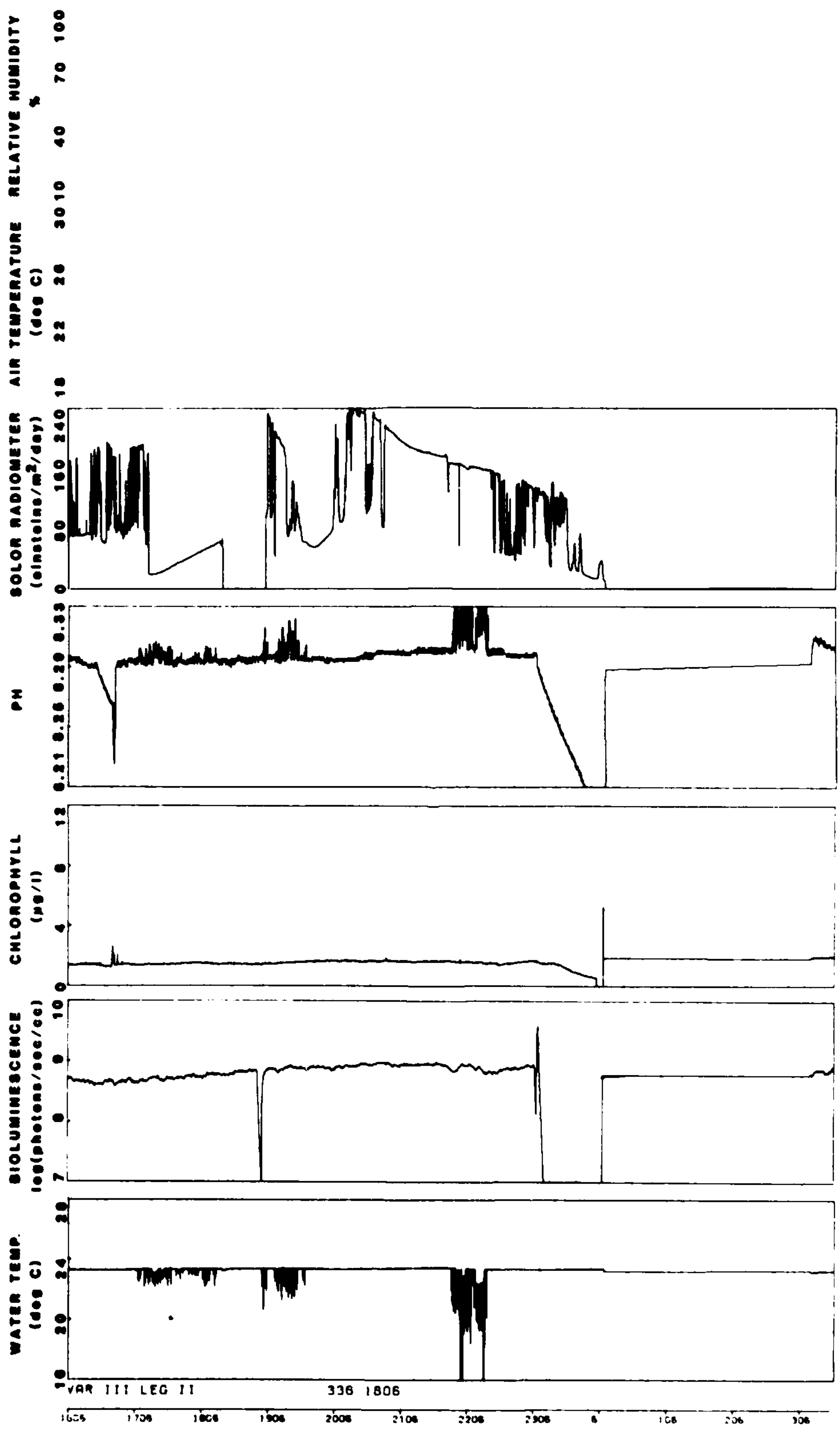

SOLOR RADIOMETER
(einsteins/m2/day)
AIR TEMPERATURE
(deg C)
RELATIVE HUMIDITY
%
PH
CHLOROPHYLL
(µg/l)
BIOLUMINESCENCE
log(photons/sec/cc)
WATER TEMP.
(deg C)
VAR III LEG II
336 1806
HOURS

Figure E-9.

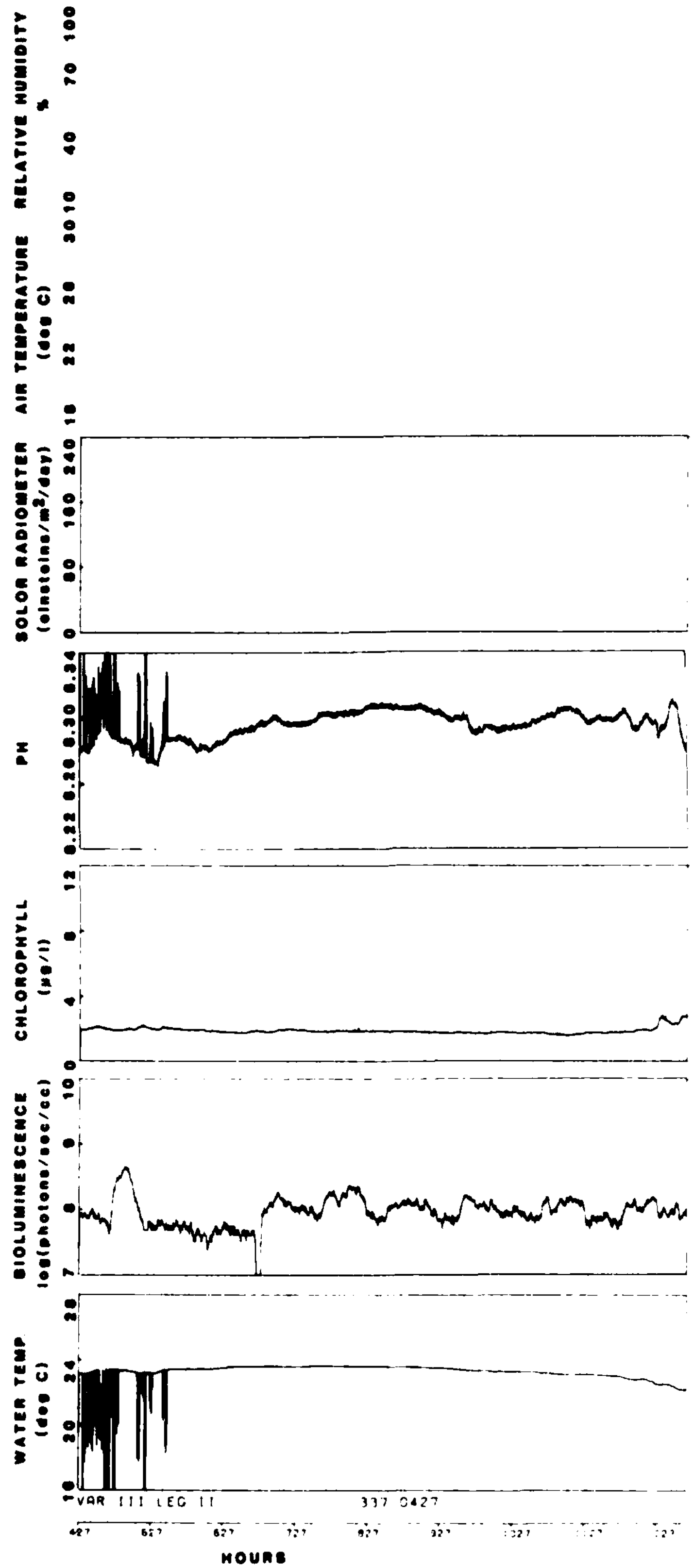

WATER TEMP. (deg C)
BIOLUMINESCENCE log(photons/sec/cc)
CHLOROPHYLL (µg/l)
PH
SOLOR RADIOMETER (einsteins/m²/day)
AIR TEMPERATURE (deg C)
RELATIVE HUMIDITY %
VAR III LEG II
337 0427
HOURS

Figure E-10.

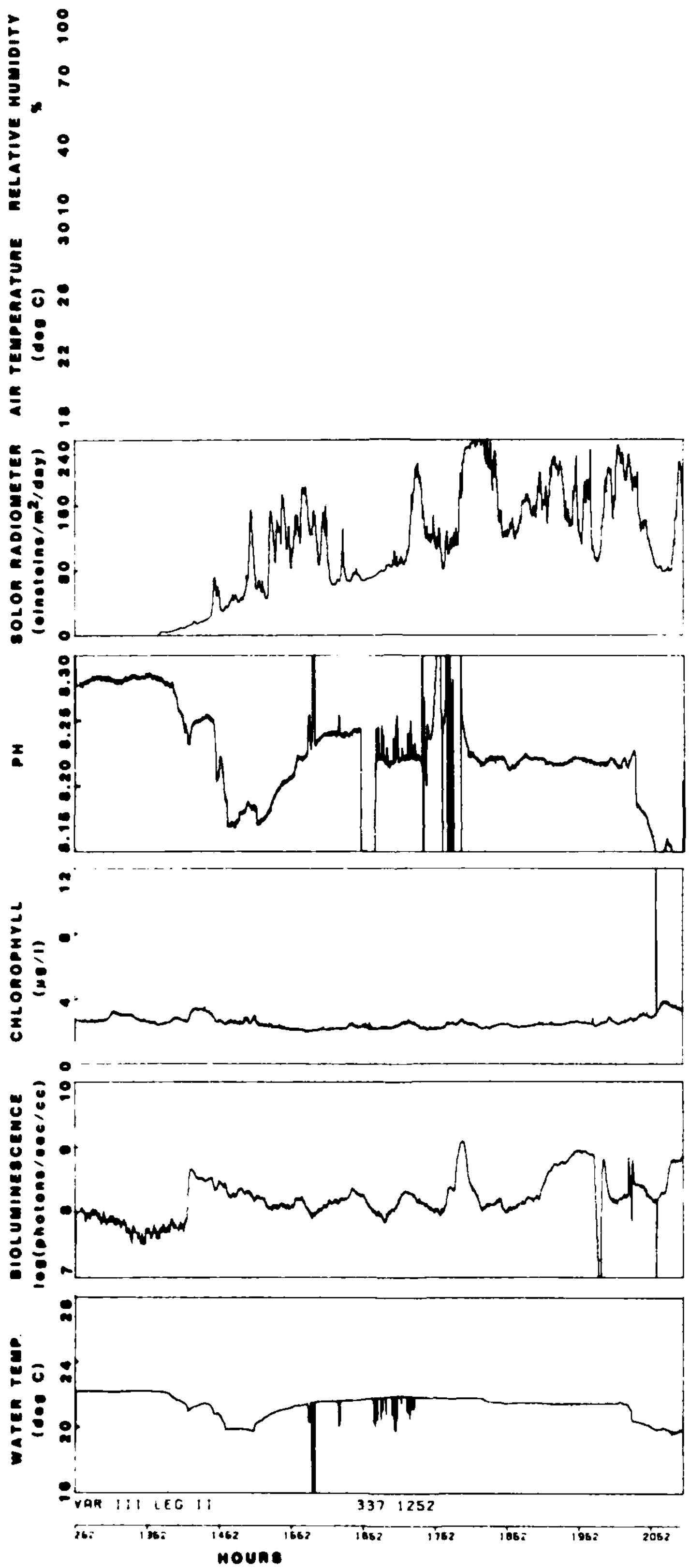
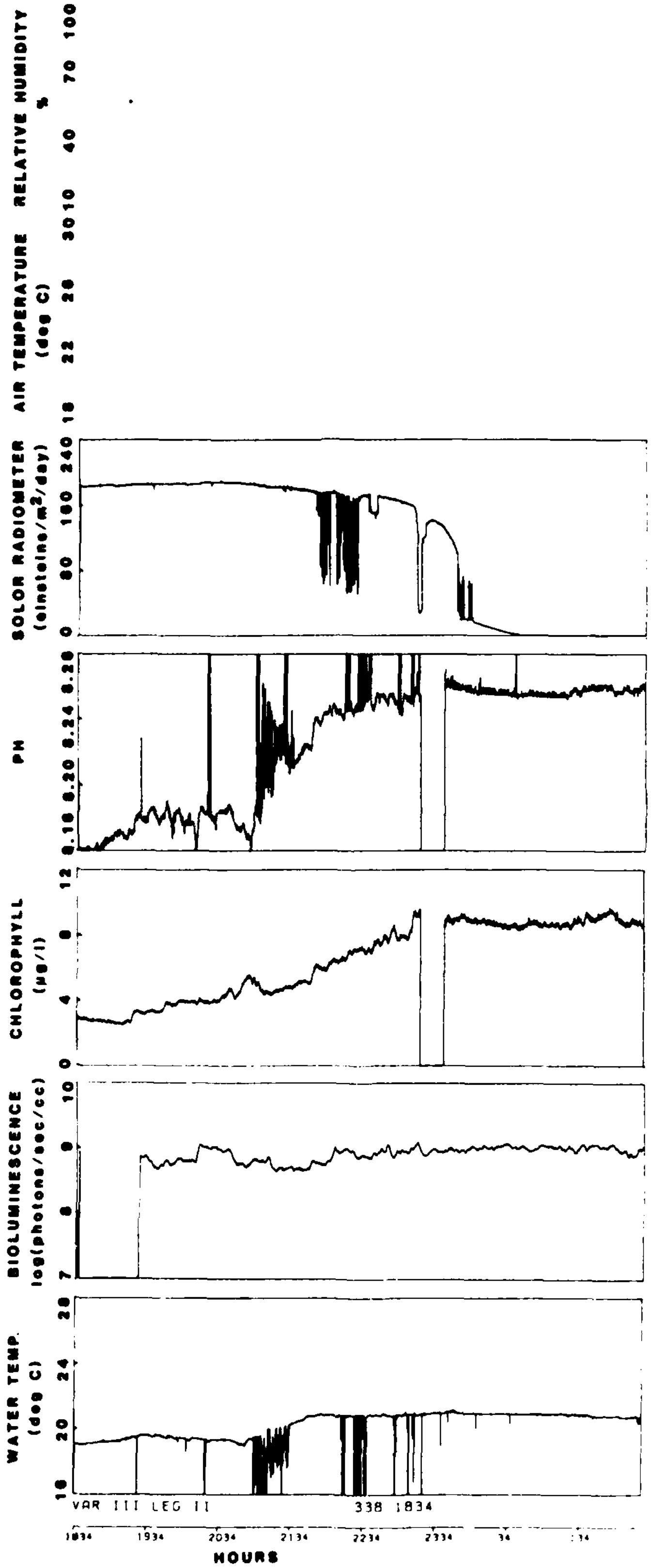

WATER TEMP.
(deg C)
BIOLUMINESCENCE
log(photons/sec/cc)
CHLOROPHYLL
(µg/l)
PH
SOLOR RADIOMETER
(einsteins/m²/day)
AIR TEMPERATURE
(deg C)
RELATIVE HUMIDITY
%
VAR III LEG II
337 1252
HOURS

Figure E-11.



SOLOR RADIOMETER (einsteins/m²/day)
0 80 160 240
PH
8.16 8.20 8.24 8.28
CHLOROPHYLL (µg/l)
0 4 8 12
BIOLUMINESCENCE log(photons/sec/cc)
7 8 9 10
WATER TEMP. (deg C)
16 20 24 28
AIR TEMPERATURE (deg C)
18 22 26 30
RELATIVE HUMIDITY %
10 40 70 100
VAR III LEG II
338 1834
1834 1934 2034 2134 2234 2334 34 134
HOURS

Figure E-12.

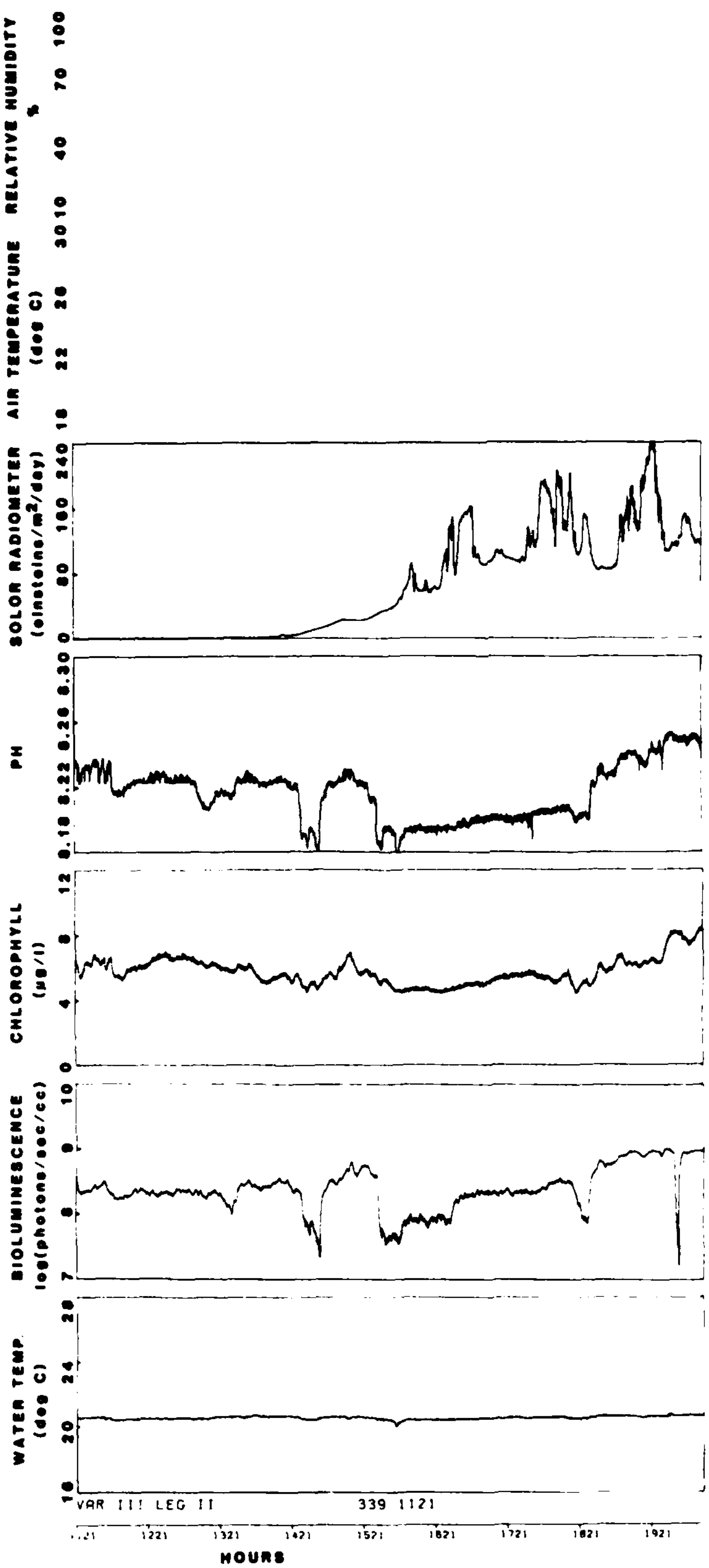

SOLOR RADIOMETER
(einsteins/m2/day)
AIR TEMPERATURE
(deg C)
RELATIVE HUMIDITY
%
PH
CHLOROPHYLL
(µg/l)
BIOLUMINESCENCE
log(photons/sec/cc)
WATER TEMP.
(deg C)
VAR III LEG II
339 1121
HOURS

Figure E-13.

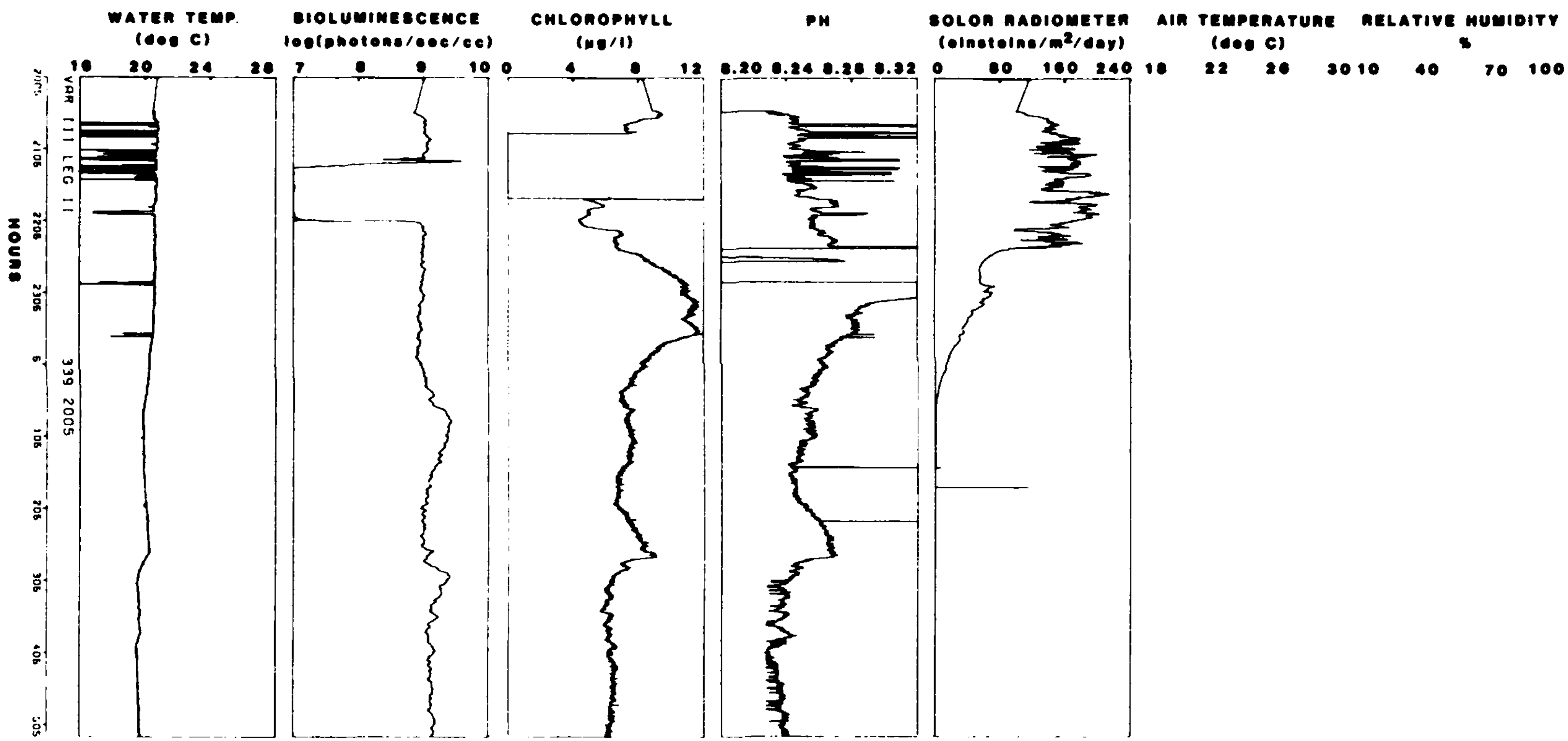
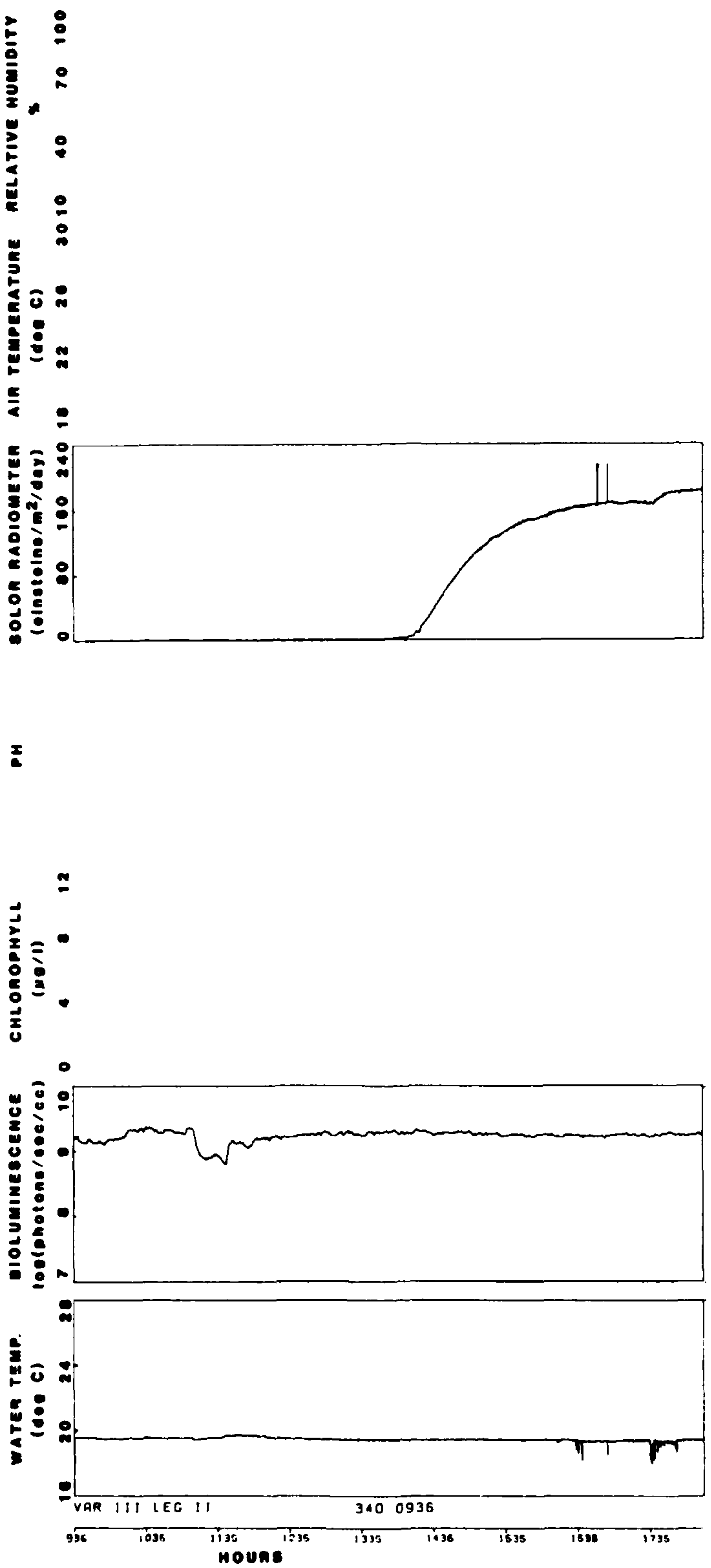
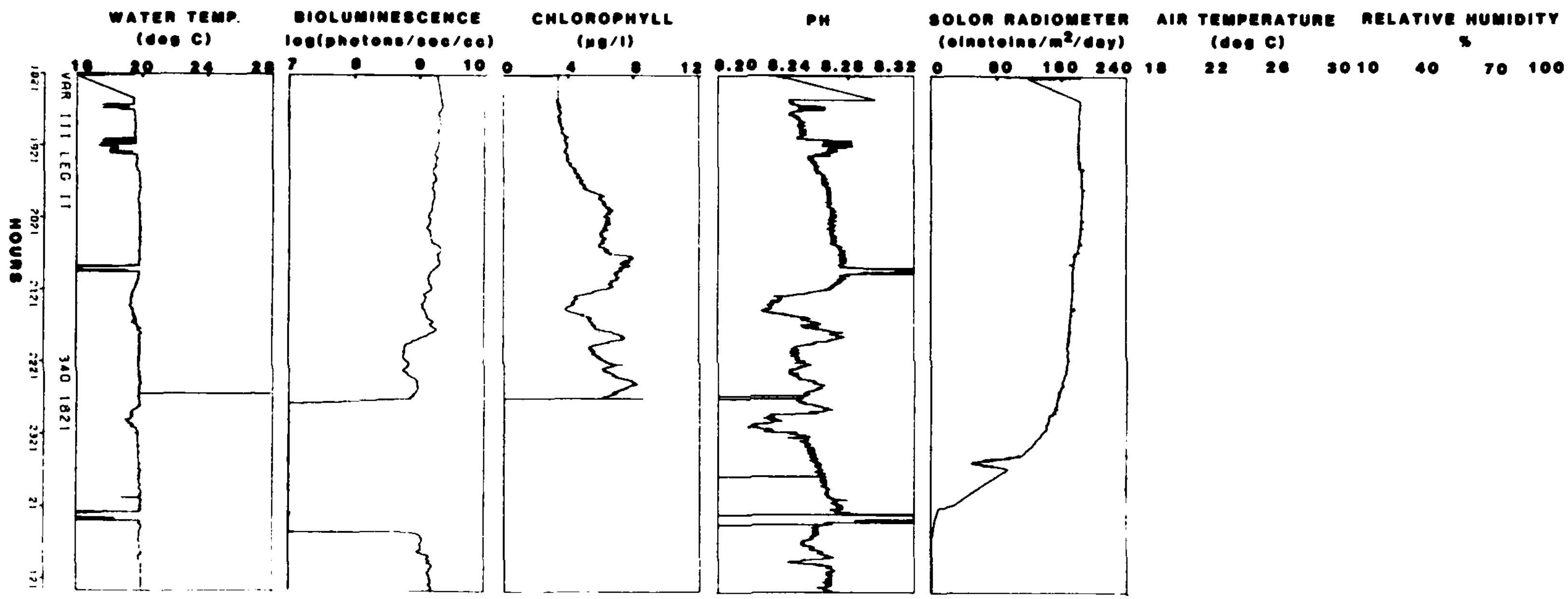

WATER TEMP. (deg C)
16 20 24 28
BIOLUMINESCENCE log(photons/sec/cc)
7 8 9 10
CHLOROPHYLL (μg/l)
0 4 8 12
PH
8.20 8.24 8.28 8.32
SOLOR RADIOMETER (einsteins/m²/day)
0 80 160 240
AIR TEMPERATURE (deg C)
18 22 26 30
RELATIVE HUMIDITY %
10 40 70 100
VAR III LEG II
339 2005
2106 2206 2306 6 106 206 306 406
HOURS

Figure E-14.



WATER TEMP. (deg C)
BIOLUMINESCENCE log(photons/sec/cc)
CHLOROPHYLL (µg/l)
PH
SOLOR RADIOMETER (einsteins/m²/day)
AIR TEMPERATURE (deg C)
RELATIVE HUMIDITY %
VAR III LEG II
340 0936
HOURS

Figure E-15.



WATER TEMP.
(deg C)
BIOLUMINESCENCE
log(photons/sec/cc)
CHLOROPHYLL
(µg/l)
PH
SOLOR RADIOMETER
(einsteins/m²/day)
AIR TEMPERATURE
(deg C)
RELATIVE HUMIDITY
%
VAR III LEG II
340 1821
HOURS

Figure E-16.

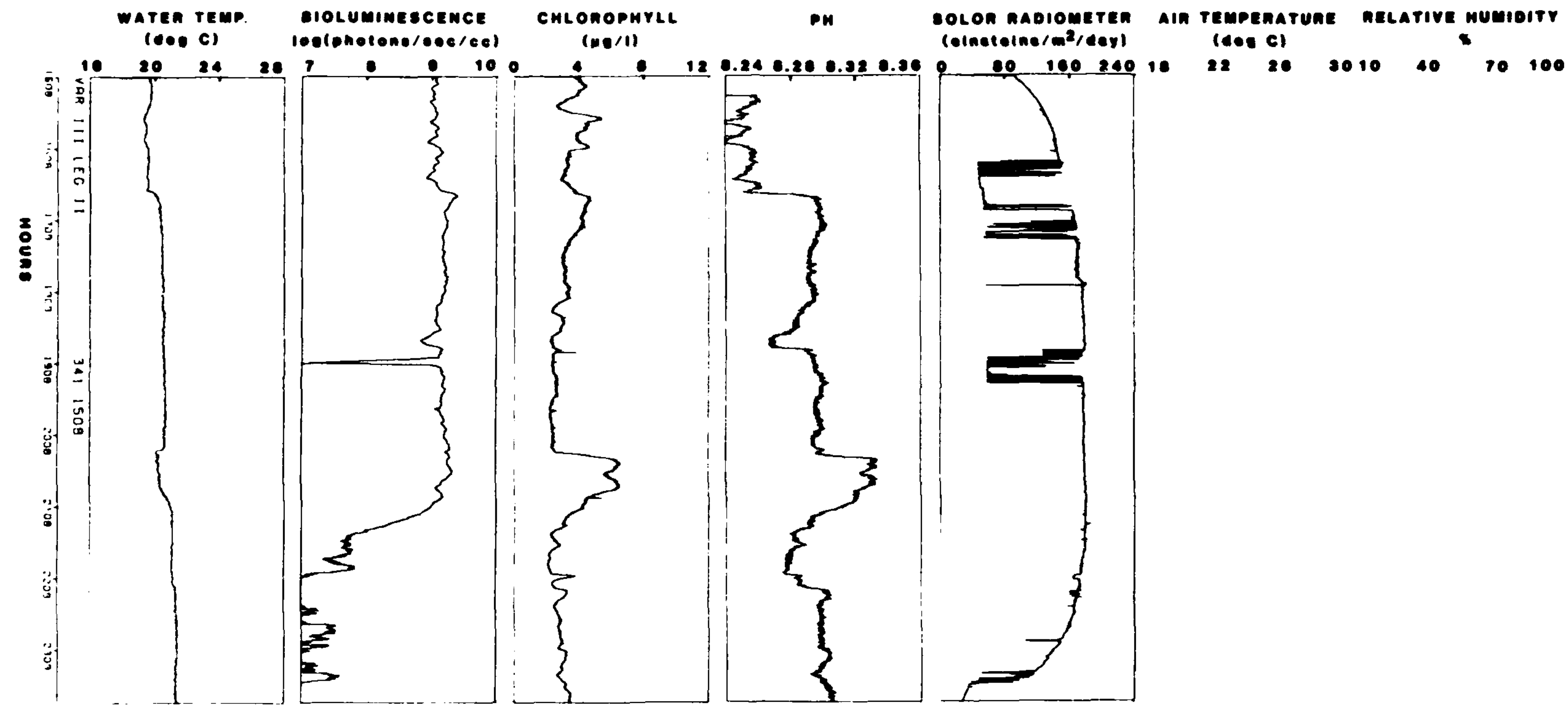

WATER TEMP. (deg C)
18 20 24 28
BIOLUMINESCENCE log(photons/sec/cc)
7 8 9 10
CHLOROPHYLL (µg/l)
0 4 8 12
PH
8.24 8.28 8.32 8.36
SOLOR RADIOMETER (einsteins/m²/day)
0 80 160 240
AIR TEMPERATURE (deg C)
18 22 26 30
RELATIVE HUMIDITY %
10 40 70 100
VAR III LEG II
341 1508
HOURS

Figure E-17.

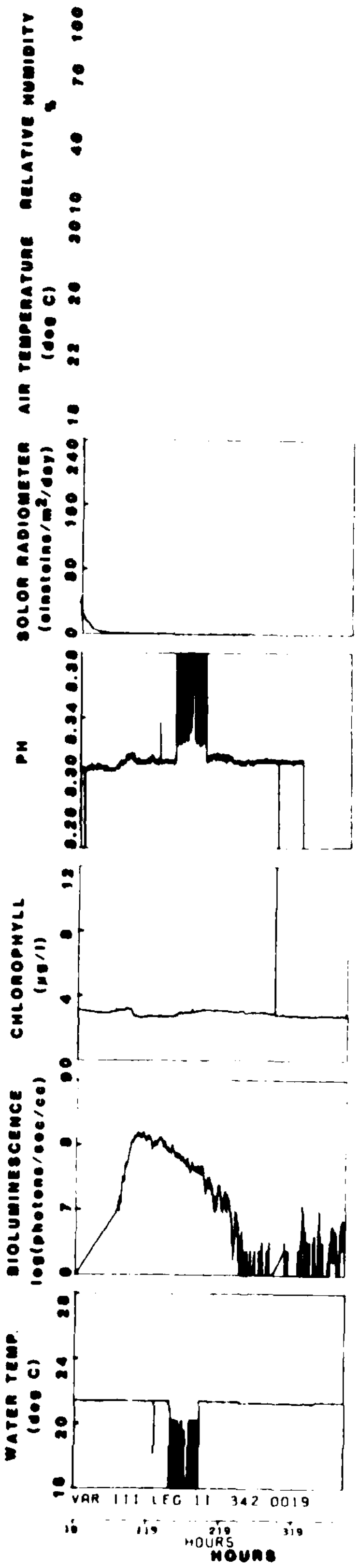

WATER TEMP. (deg C)
BIOLUMINESCENCE log(photons/sec/cc)
CHLOROPHYLL (µg/l)
PH
SOLOR RADIOMETER (einsteins/m2/day)
AIR TEMPERATURE (deg C)
RELATIVE HUMIDITY %
VAR III LEG II 342 0019
HOURS

Figure E-18.

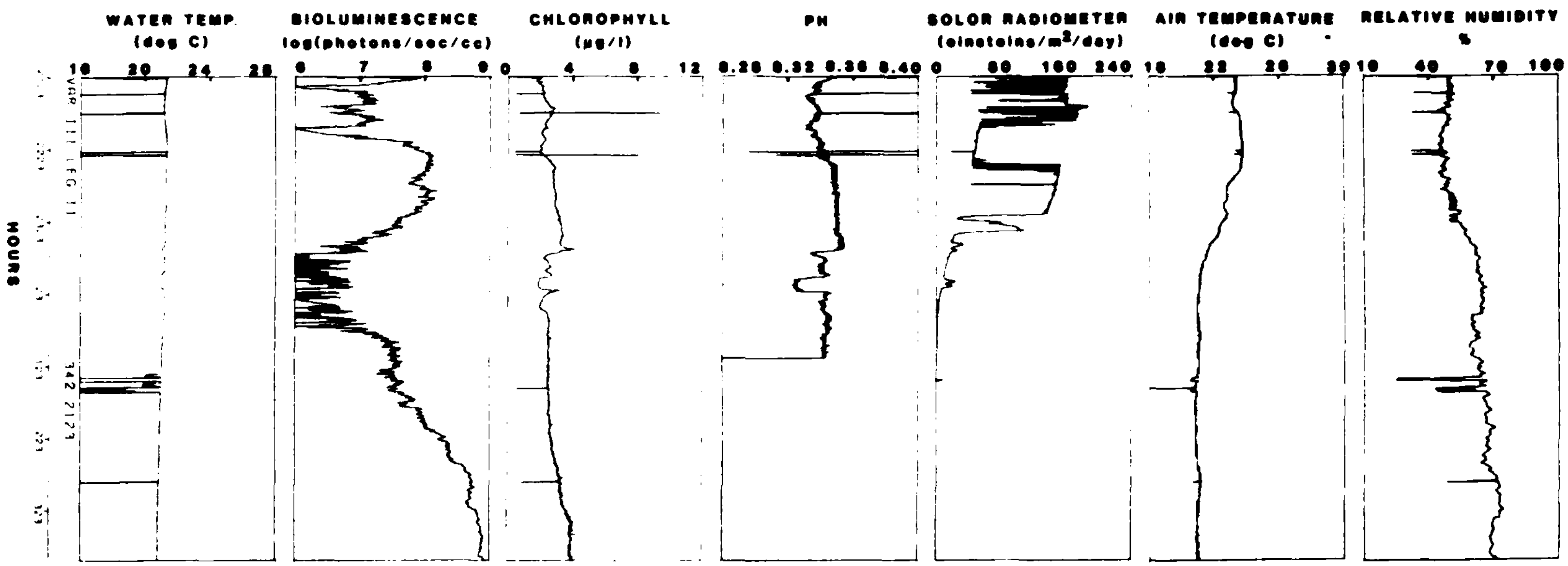
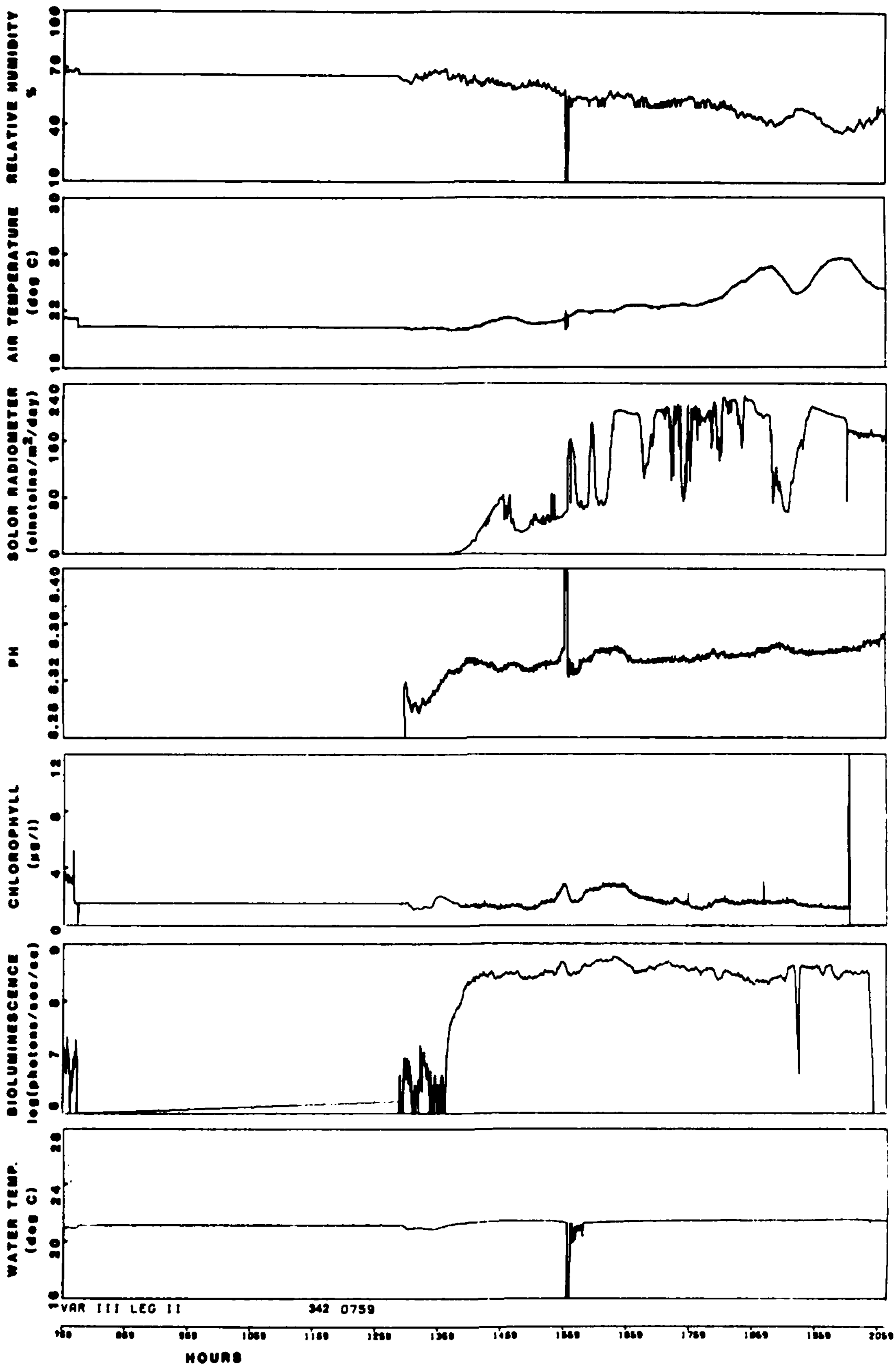
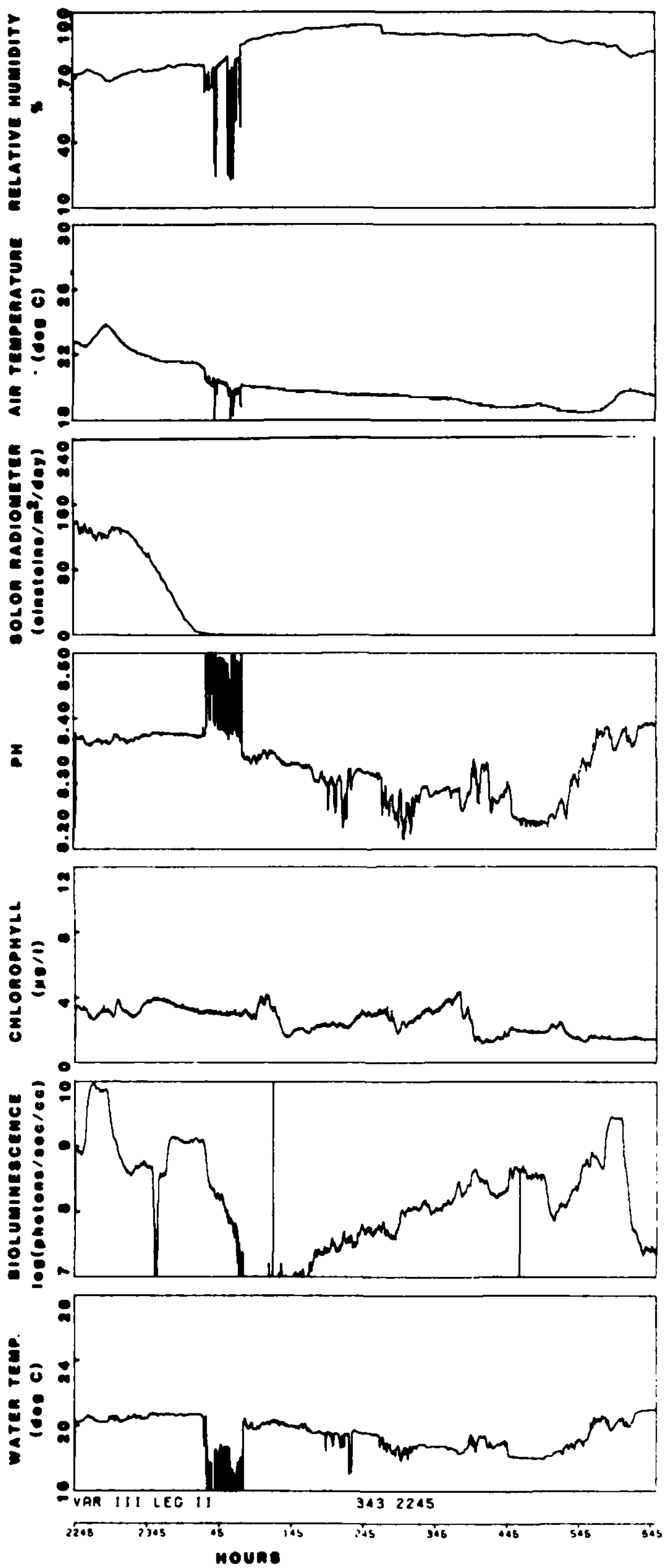

WATER TEMP.
(deg C)
BIOLUMINESCENCE
log(photons/sec/cc)
CHLOROPHYLL
(µg/l)
PH
SOLOR RADIOMETER
(einsteins/m²/day)
AIR TEMPERATURE
(deg C)
RELATIVE HUMIDITY
%
HOURS
342 2123

Figure E-19.



RELATIVE HUMIDITY %
AIR TEMPERATURE (deg C)
SOLOR RADIOMETER (einsteins/m2/day)
PH
CHLOROPHYLL (ug/l)
BIOLUMINESCENCE log(photons/sec/cc)
WATER TEMP. (deg C)
VAR III LEG II
342 0759
HOURS

Figure E-20.



RELATIVE HUMIDITY %
AIR TEMPERATURE (deg C)
SOLOR RADIOMETER (einsteins/m2/day)
PH
CHLOROPHYLL (uG/l)
BIOLUMINESCENCE log(photons/sec/cc)
WATER TEMP. (deg C)
VAR III LEG II
343 2245
HOURS

Figure E-21.

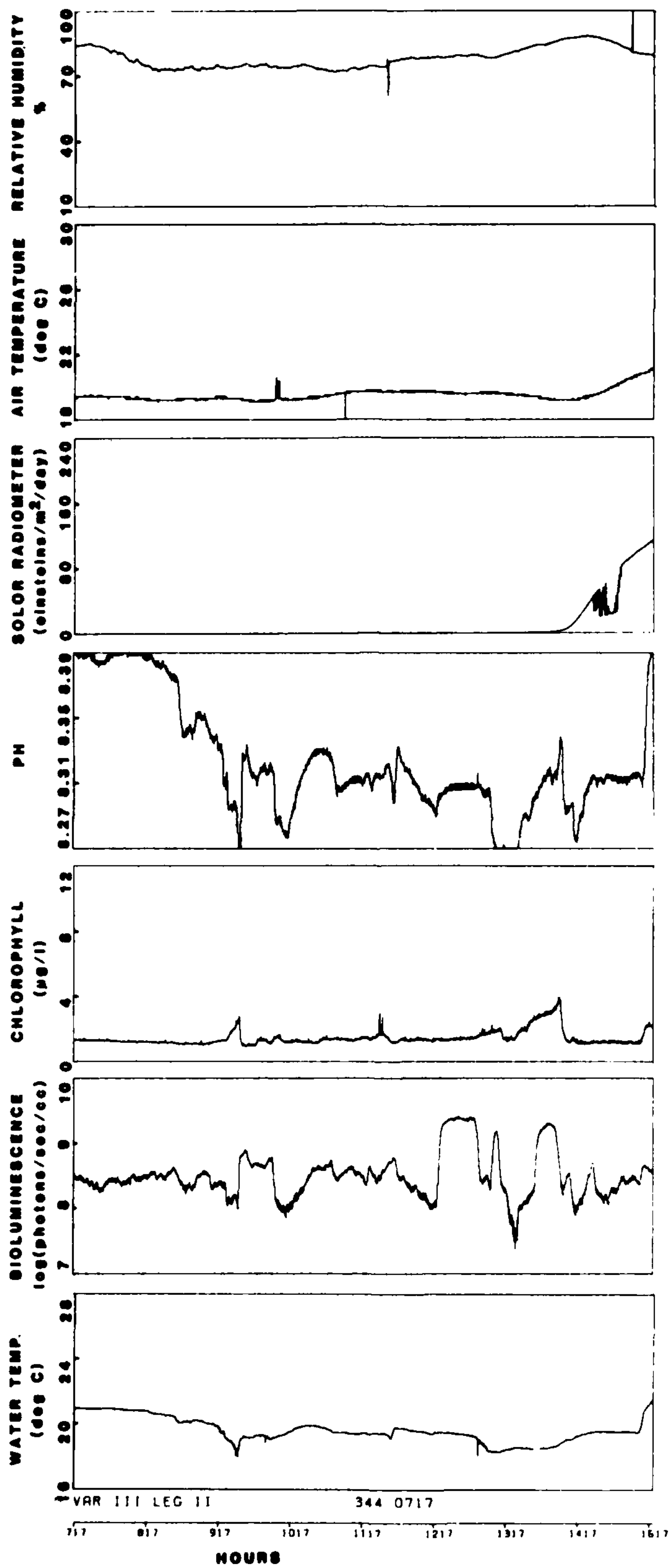

RELATIVE HUMIDITY %
AIR TEMPERATURE (deg C)
SOLOR RADIOMETER (einsteins/m2/day)
PH
CHLOROPHYLL (µg/l)
BIOLUMINESCENCE log(photons/sec/cc)
WATER TEMP. (deg C)
VAR III LEG II
344 0717
HOURS

Figure E-22.

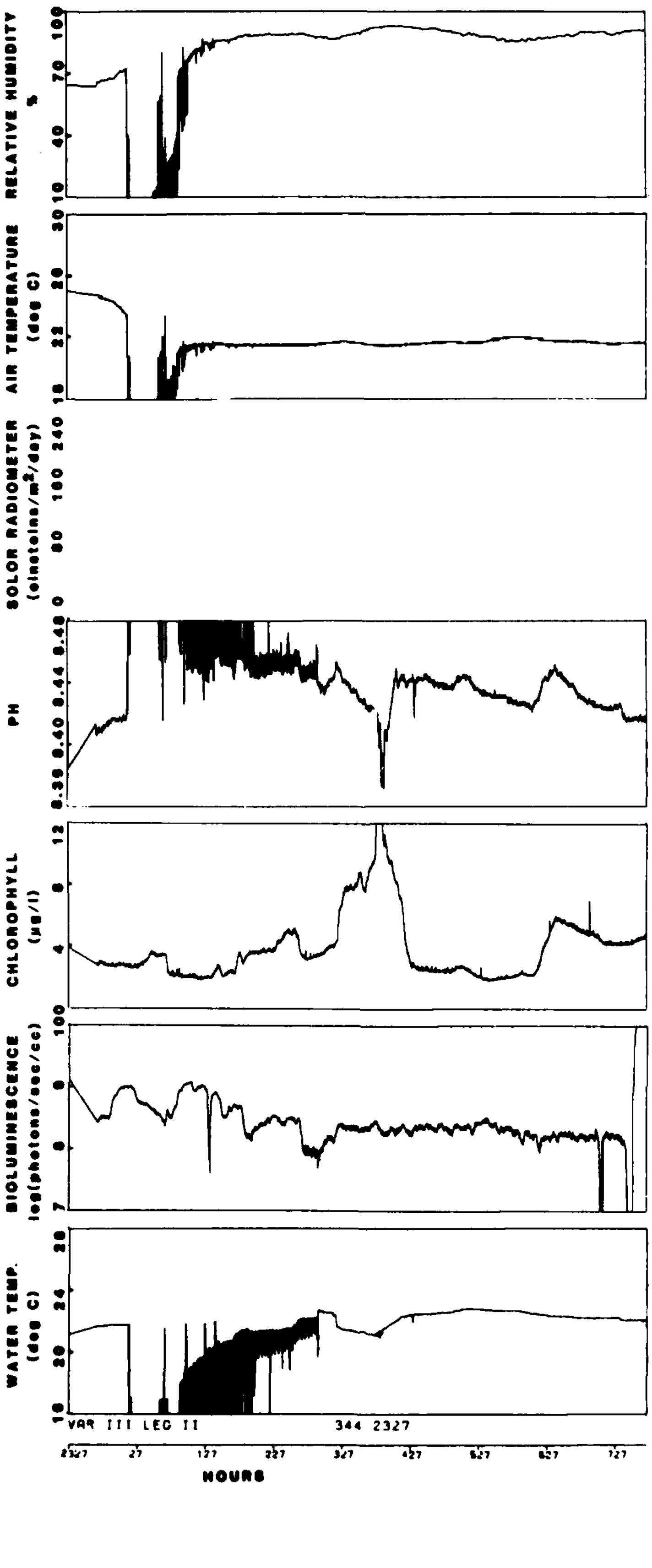

RELATIVE HUMIDITY %
AIR TEMPERATURE (deg C)
SOLOR RADIOMETER (einsteins/m2/day)
PH
CHLOROPHYLL (µg/l)
BIOLUMINESCENCE log(photons/sec/cc)
WATER TEMP. (deg C)
VAR III LEG II
344 2327
HOURS

Figure E-23.

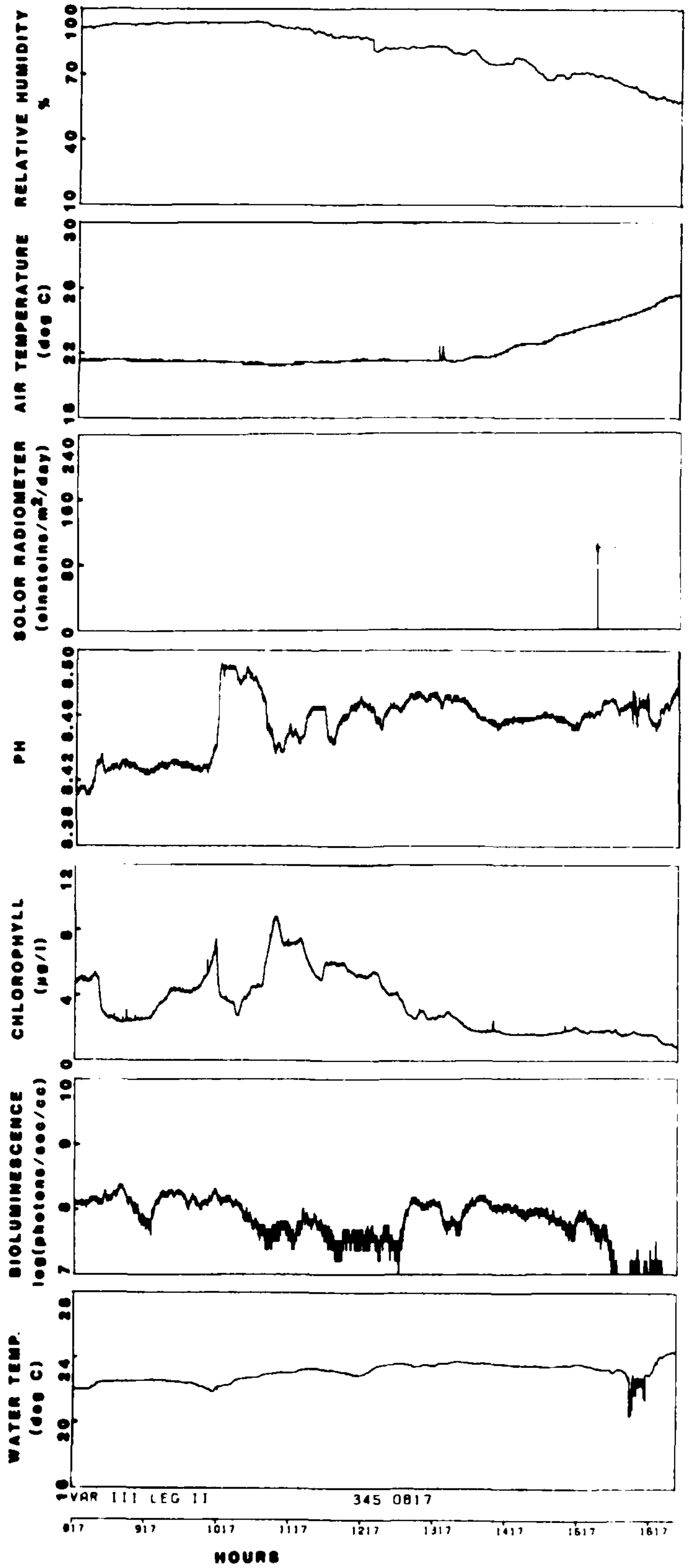

RELATIVE HUMIDITY %
AIR TEMPERATURE (deg C)
SOLOR RADIOMETER (einsteins/m2/day)
PH
CHLOROPHYLL (µg/l)
BIOLUMINESCENCE log(photons/sec/cc)
WATER TEMP. (deg C)
VAR III LEG II
345 0817
817 917 1017 1117 1217 1317 1417 1517 1617
HOURS

Figure E-24.

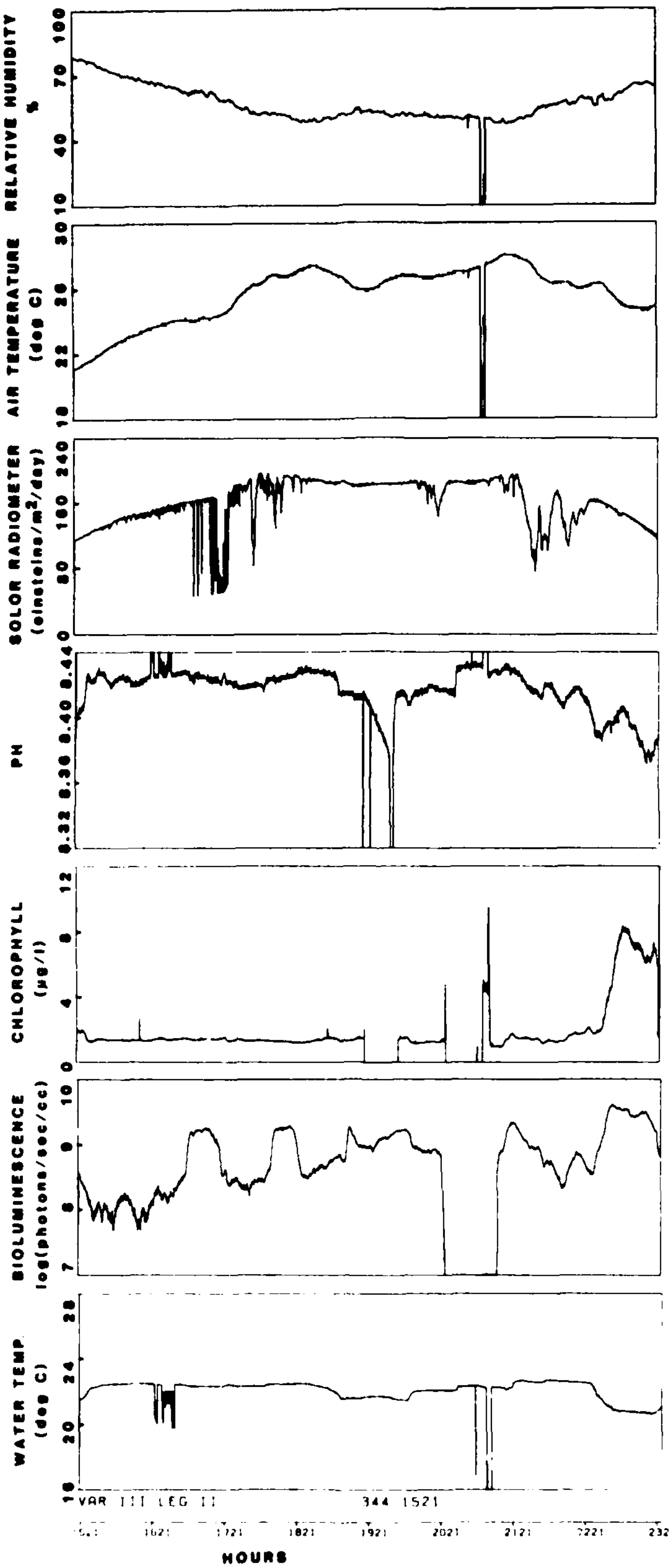

RELATIVE HUMIDITY %
AIR TEMPERATURE (deg C)
SOLOR RADIOMETER (einsteins/m²/day)
PH
CHLOROPHYLL (µg/l)
BIOLUMINESCENCE log(photons/sec/cc)
WATER TEMP. (deg C)
VAR III LEG II
344 1521
HOURS

Figure E-25.

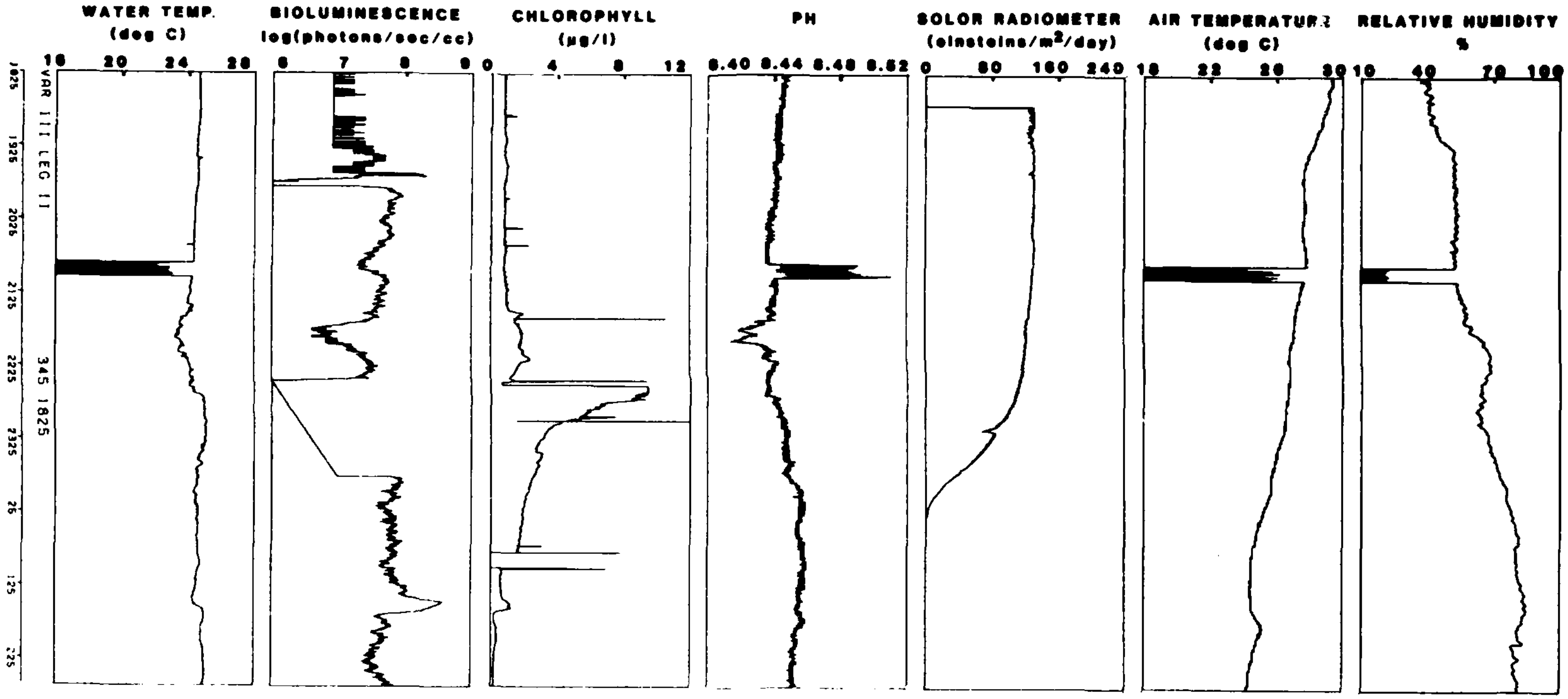

WATER TEMP.
(deg C)
BIOLUMINESCENCE
log(photons/sec/cc)
CHLOROPHYLL
(μg/l)
PH
SOLOR RADIOMETER
(einsteins/m²/day)
AIR TEMPERATURE
(deg C)
RELATIVE HUMIDITY
%
VAR III LEG II
345 1825
HOURS

Figure E-26.

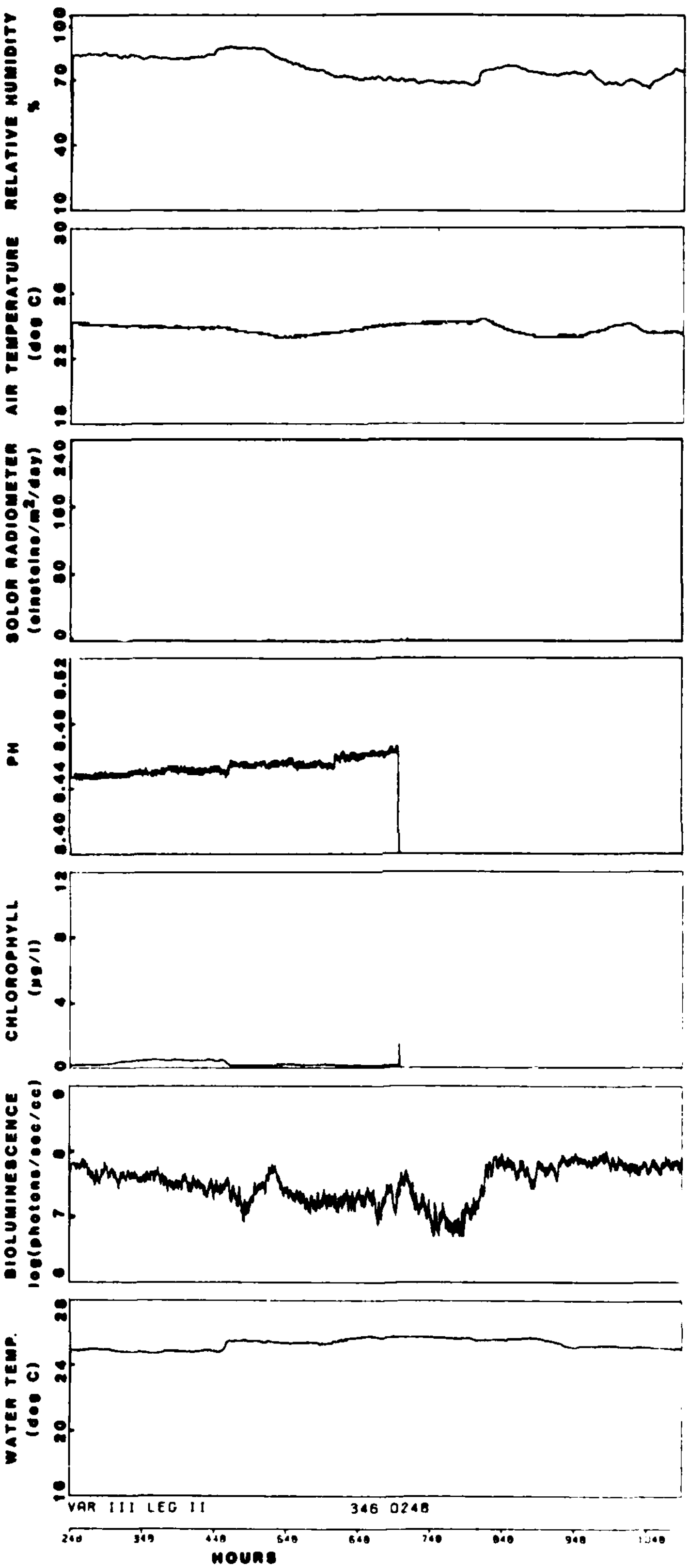

RELATIVE HUMIDITY %
AIR TEMPERATURE (deg C)
SOLOR RADIOMETER (einsteins/m2/day)
PH
CHLOROPHYLL (µg/l)
BIOLUMINESCENCE log(photons/sec/cc)
WATER TEMP. (deg C)
VAR III LEG II
346 0248
HOURS

Figure E-27.

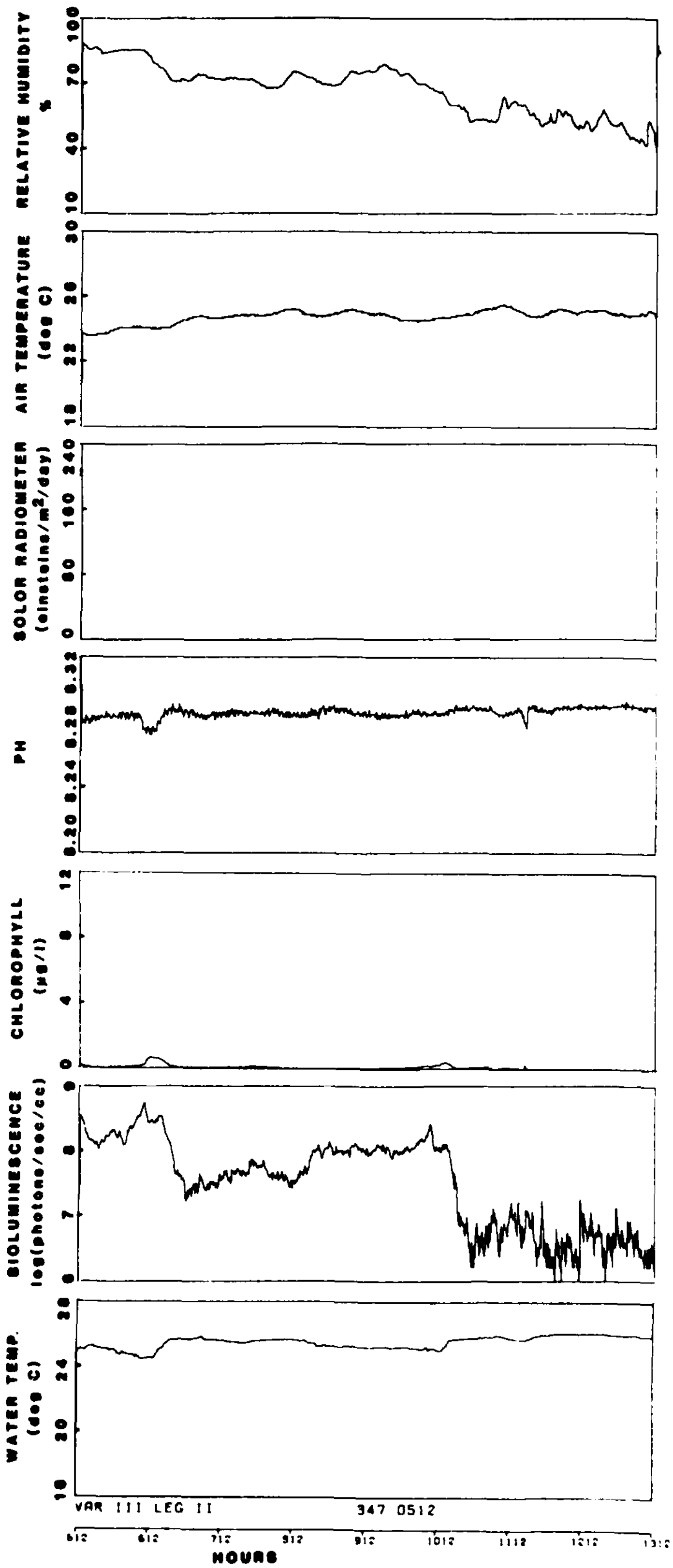
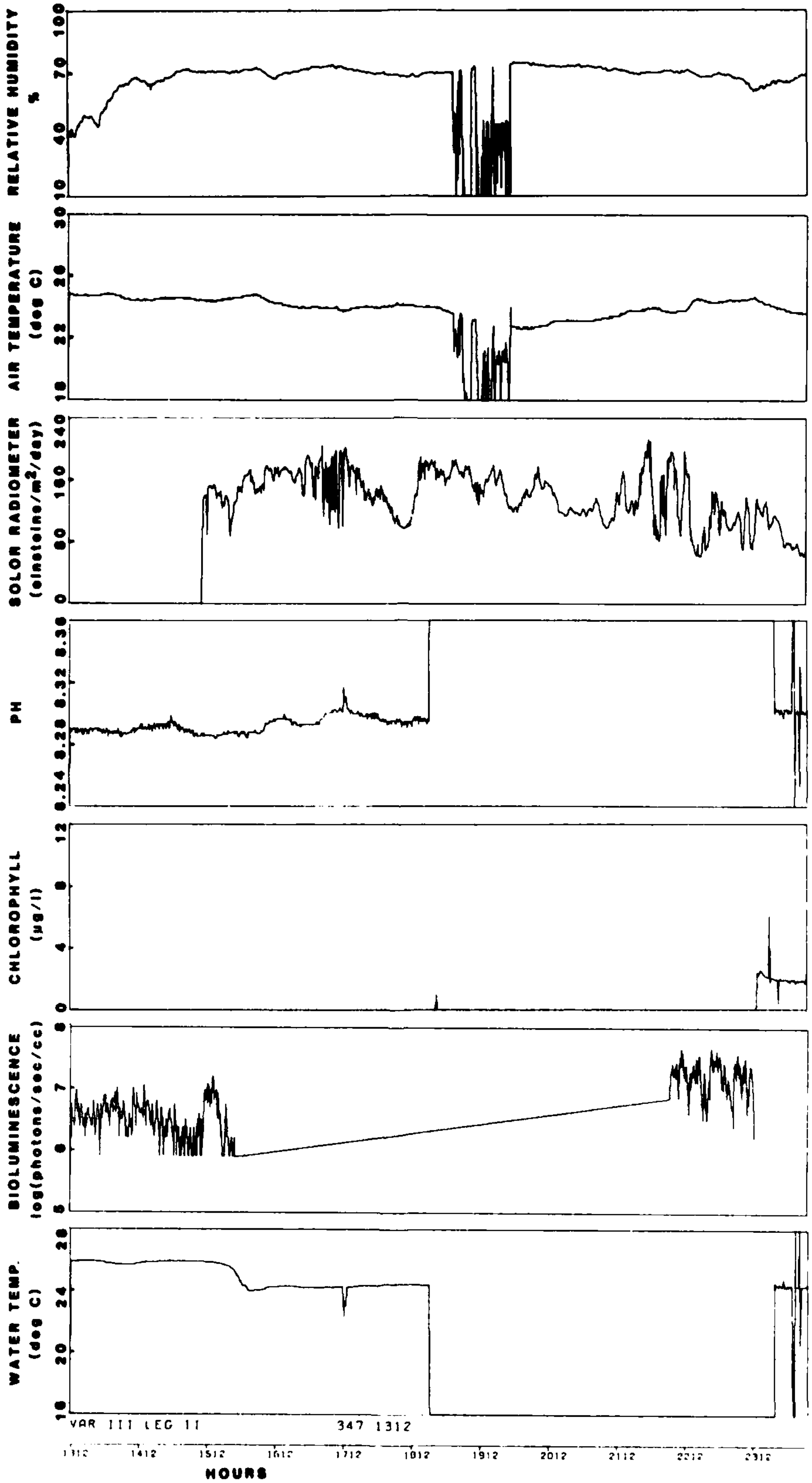

RELATIVE HUMIDITY %
AIR TEMPERATURE (deg C)
SOLOR RADIOMETER (einsteins/m2/day)
PH
CHLOROPHYLL (µg/l)
BIOLUMINESCENCE log(photons/sec/cc)
WATER TEMP. (deg C)
VAR III LEG II
347 0512
HOURS

Figure E-28.



RELATIVE HUMIDITY
%
AIR TEMPERATURE
(deg C)
SOLOR RADIOMETER
(einsteins/m²/day)
PH
CHLOROPHYLL
(µg/l)
BIOLUMINESCENCE
log(photons/sec/cc)
WATER TEMP.
(deg C)
VAR III LEG II
347 1312
HOURS

Figure E-29.

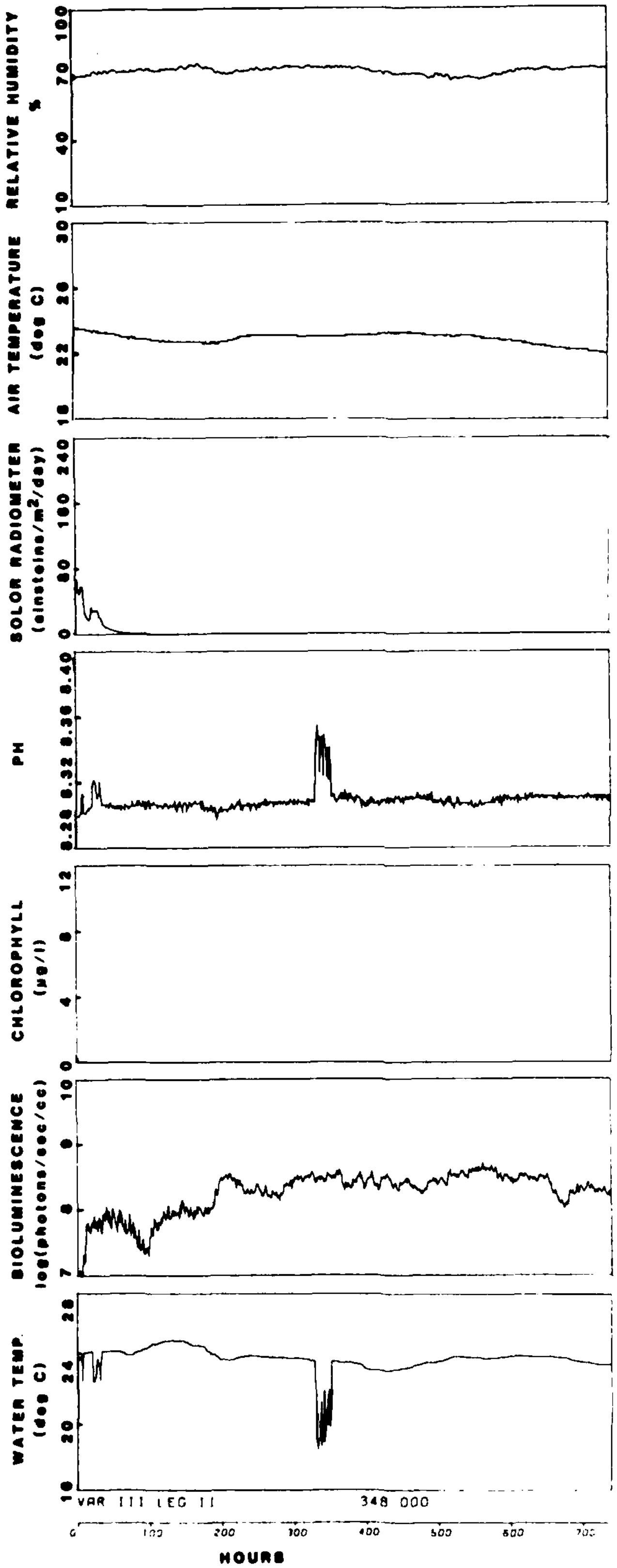
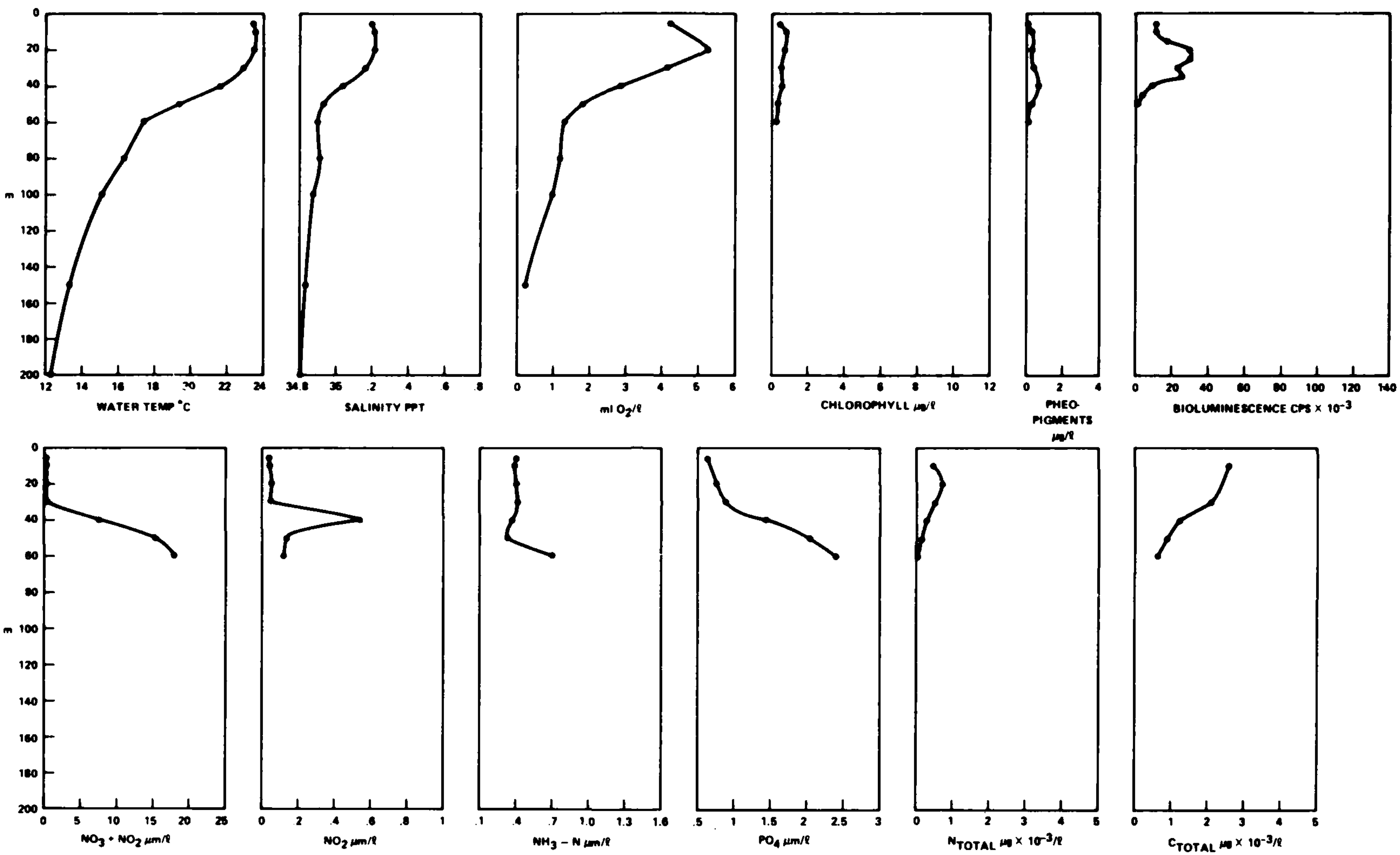

RELATIVE HUMIDITY %
AIR TEMPERATURE (deg C)
SOLOR RADIOMETER (einsteins/m2/day)
PH
CHLOROPHYLL (µg/l)
BIOLUMINESCENCE log(photons/sec/cc)
WATER TEMP. (deg C)
VAR III LEG II
348 000
HOURS

Figure E-30.

APPENDIX F
PLOTS OF VERTICAL STATION DATA

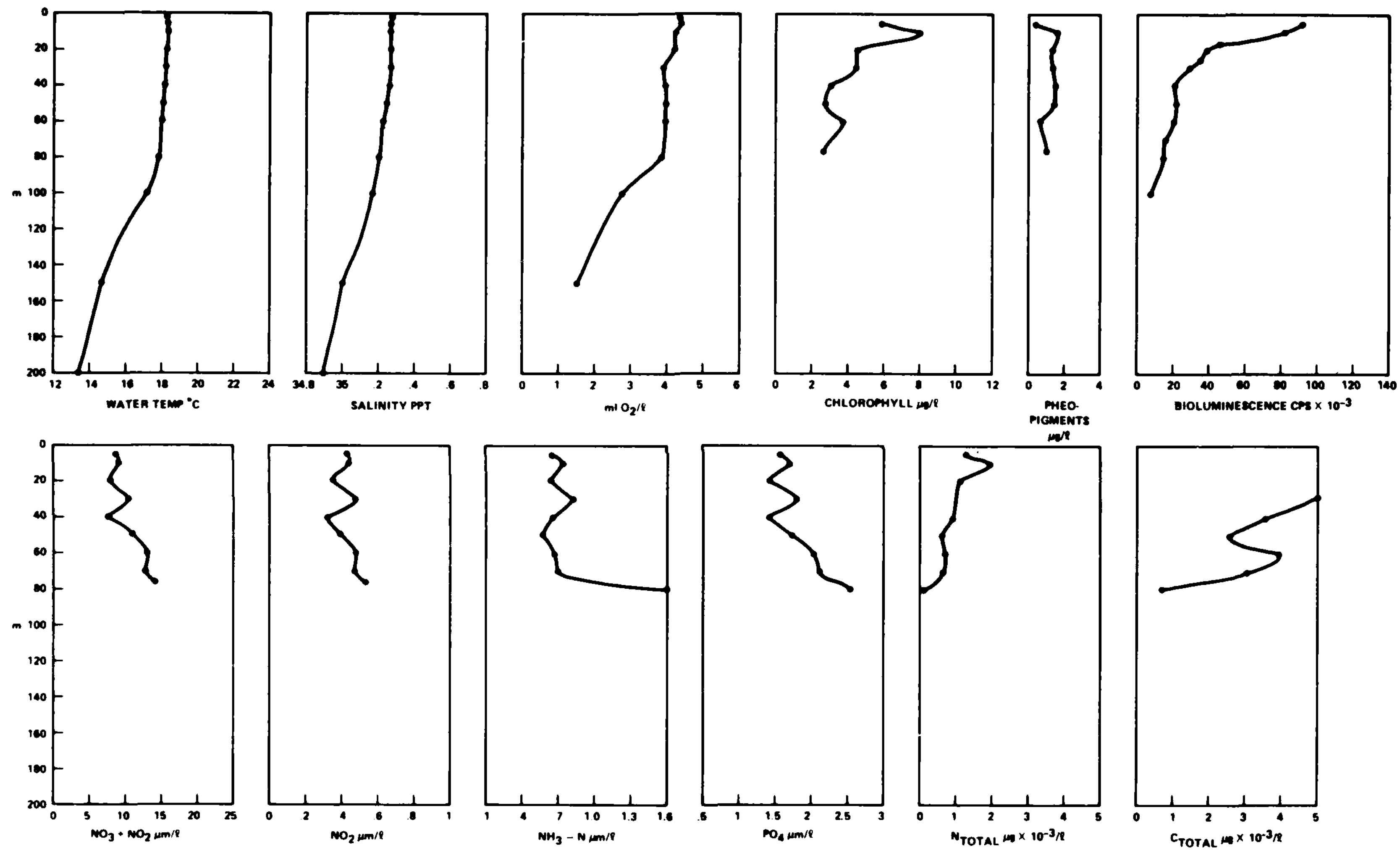
Figures F-1 to F-10 present vertical station data for temperature, salinity, oxygen, chlorophyll *a*, phaeo-pigments, bioluminescence, nutrients, and particulate carbon and nitrogen. Details of the measurement techniques are presented in the methods section of this report. Temperature and salinity data were derived from CTD casts. Samples for oxygen, chlorophyll *a*, and phaeo-pigment analyses were collected in conjunction with CTD casts using rosette-mounted Niskin bottles. A separate bioluminescence cast using the submersible bathyphotometer was made at each station. Samples for nutrient analyses and particulate carbon and nitrogen were collected from water pumped to the surface from a hose attached to the bathyphotometer. Units for each parameter are indicated on the figure. Bioluminescence values are plotted as counts per second (cps)/1000. To convert to photons/s/cc multiply by 2.5×10^4. Data are available for the following stations:

Figure Number	Station Number
F-1	6/1
F-2	8/1
F-3	8/2
F-4	8/3
F-5	9/1
F-6	9/2
F-7	9/3
F-8	10/2
F-9	10/3
F-10	10/4



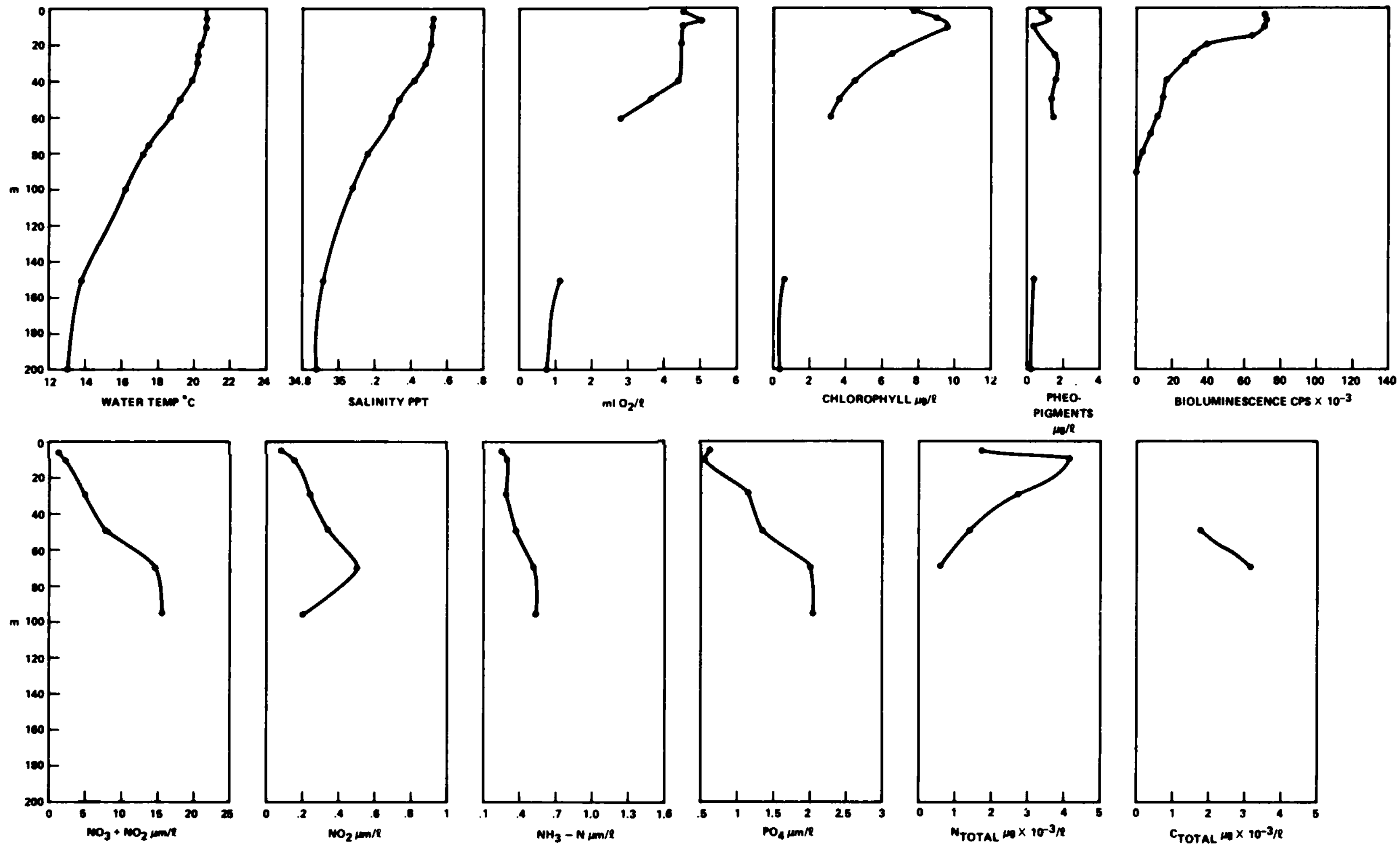
6/1/H,B VARIFRONT III LEG II 11/30/81

Figure F-1.



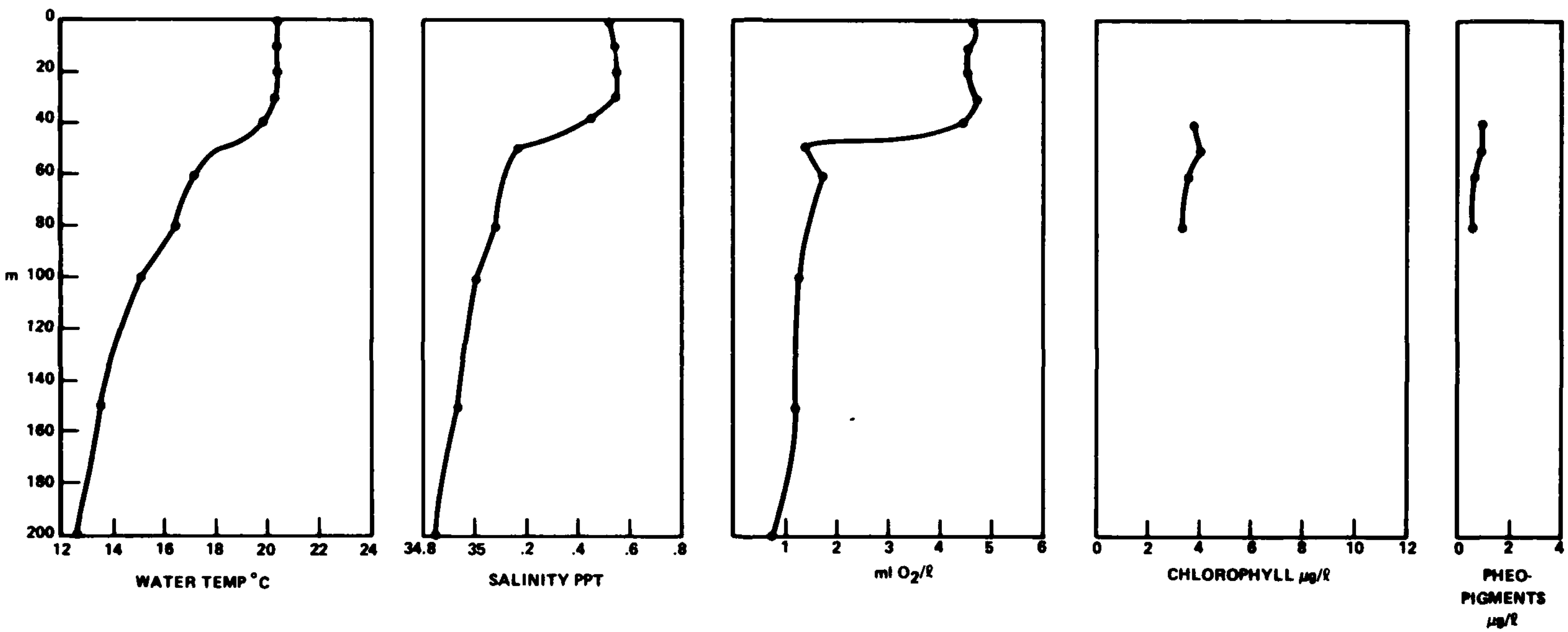
8/1/H,B VARIFRONT III LEG II 12/4/81

Figure F-2.



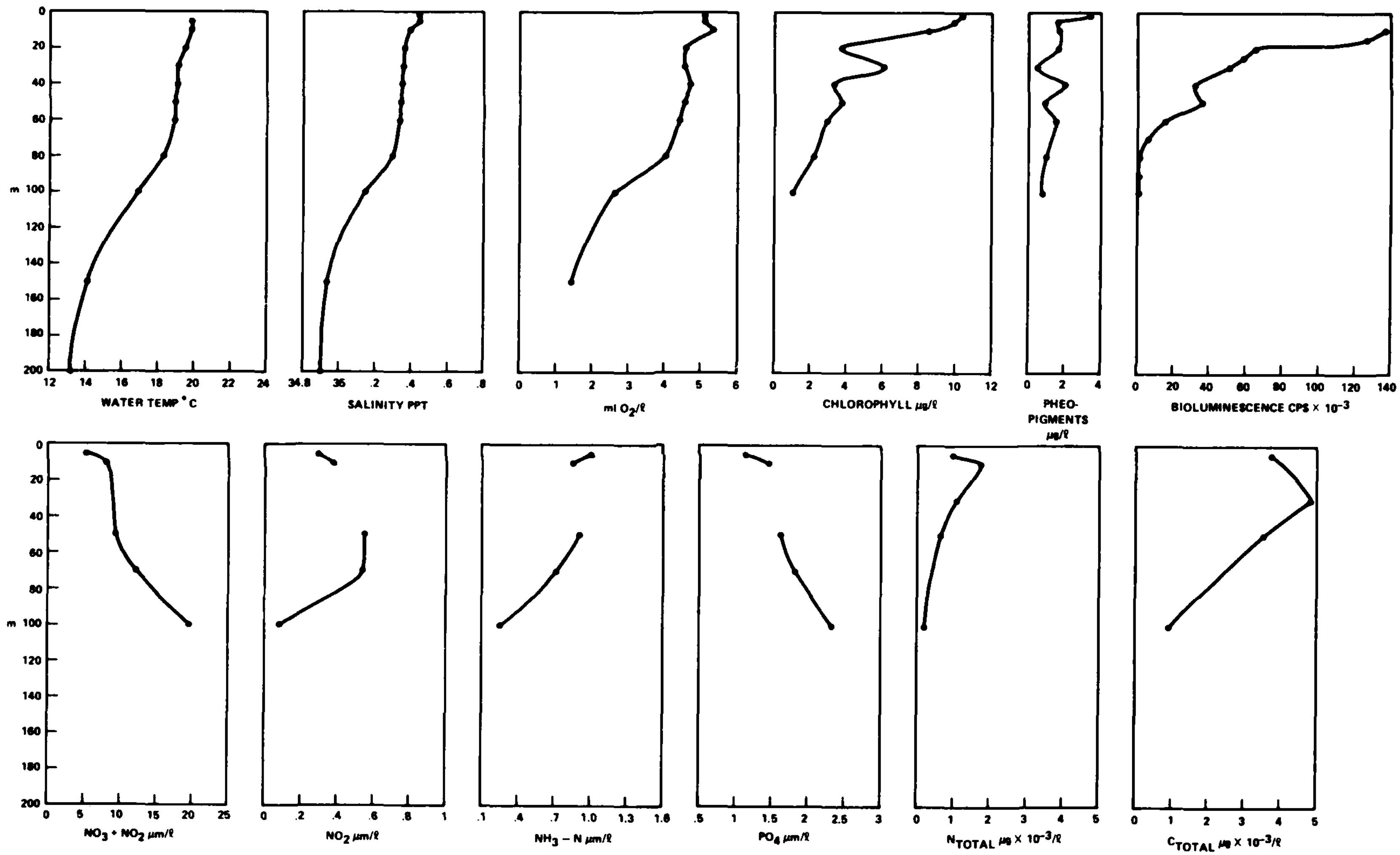
8/2/H,B VARIFRONT III LEG II 12/4/81

Figure F-3.



8/3/H VARIFRONT III LEG II 12/5/81

Figure F-4.

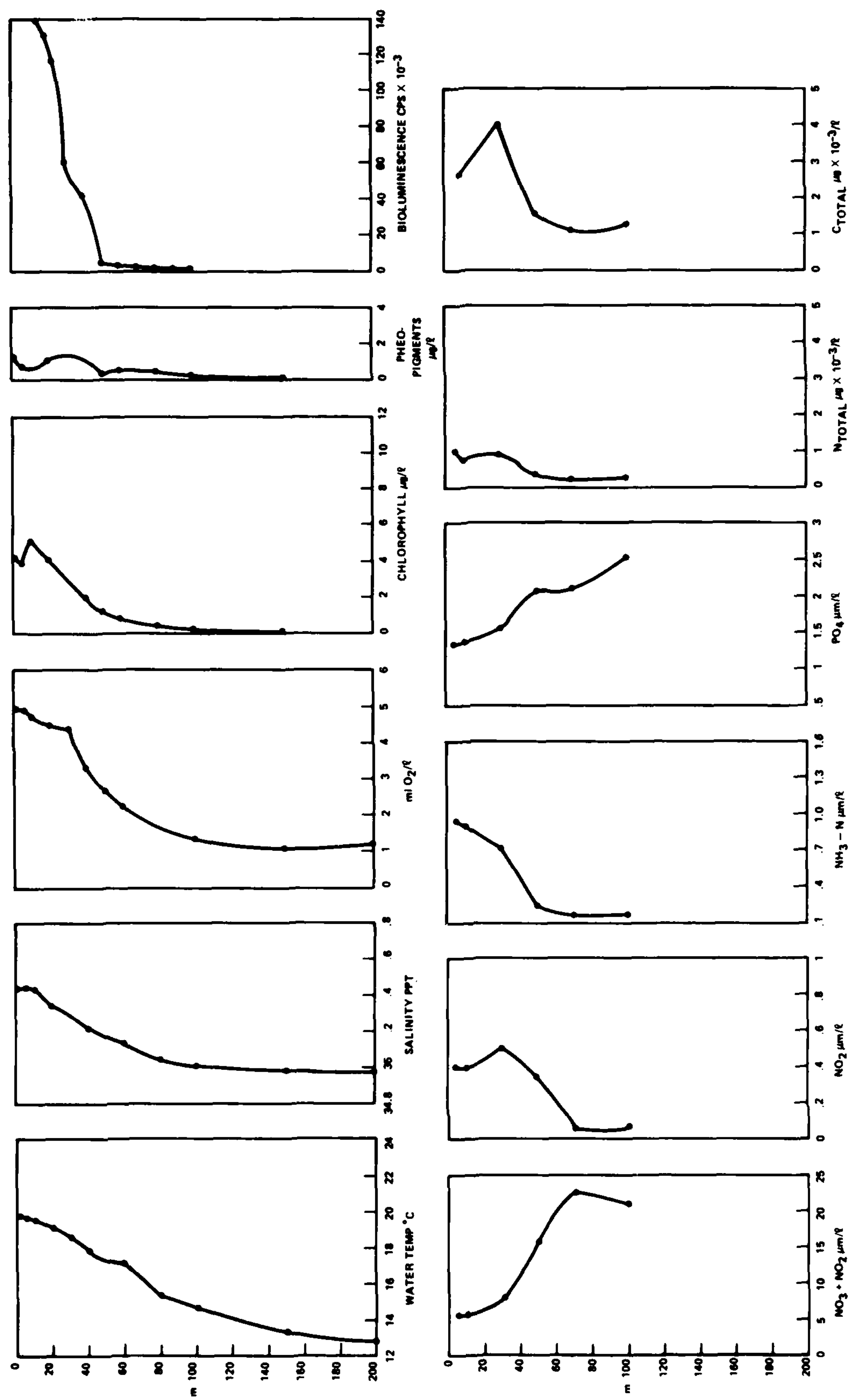


9/1/H,B VARIFRONT III LEG II 12/5/81

Figure F-5.

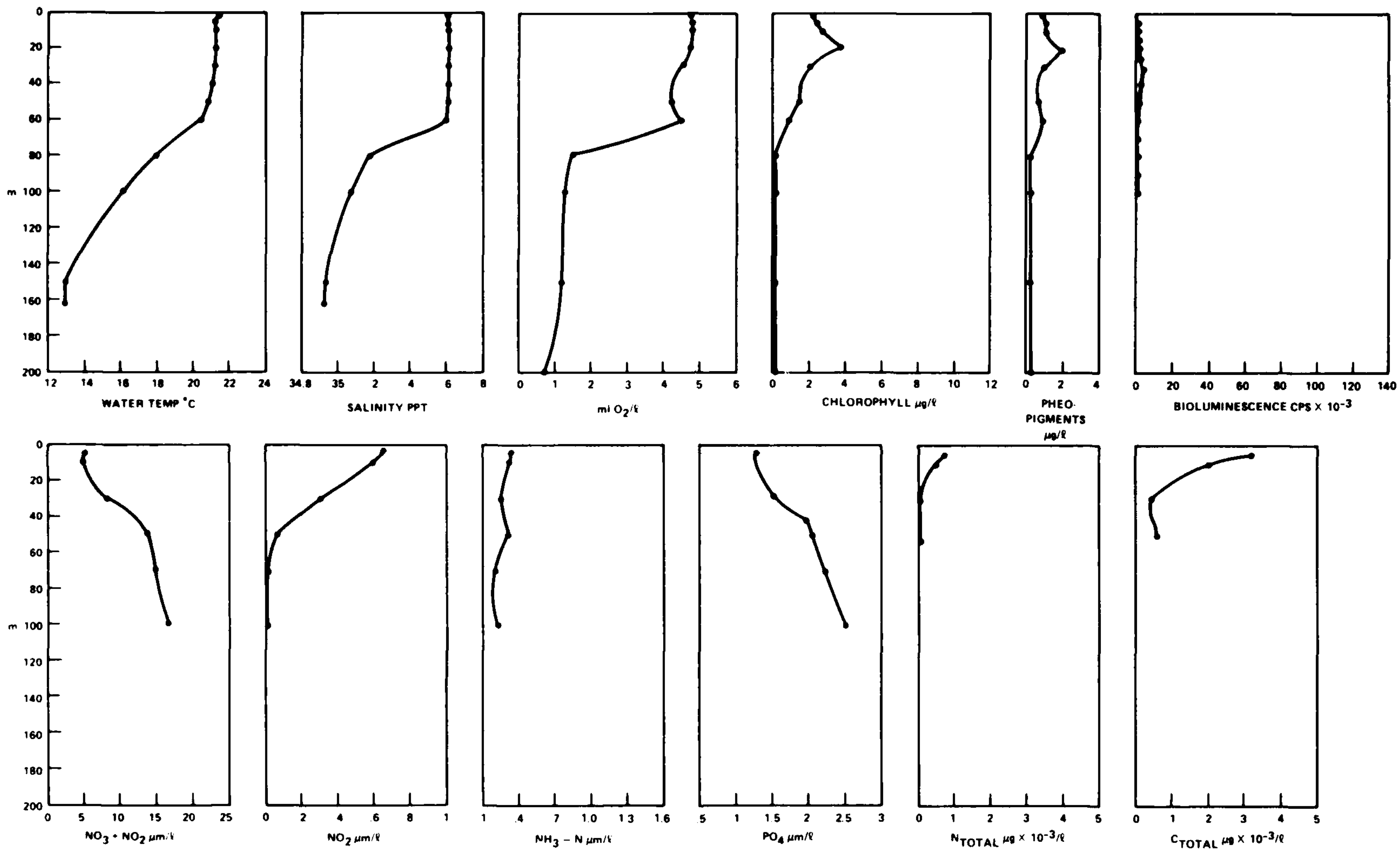
9/2/H VARIFRONT III LEG II 12/6/81

Figure F-6.



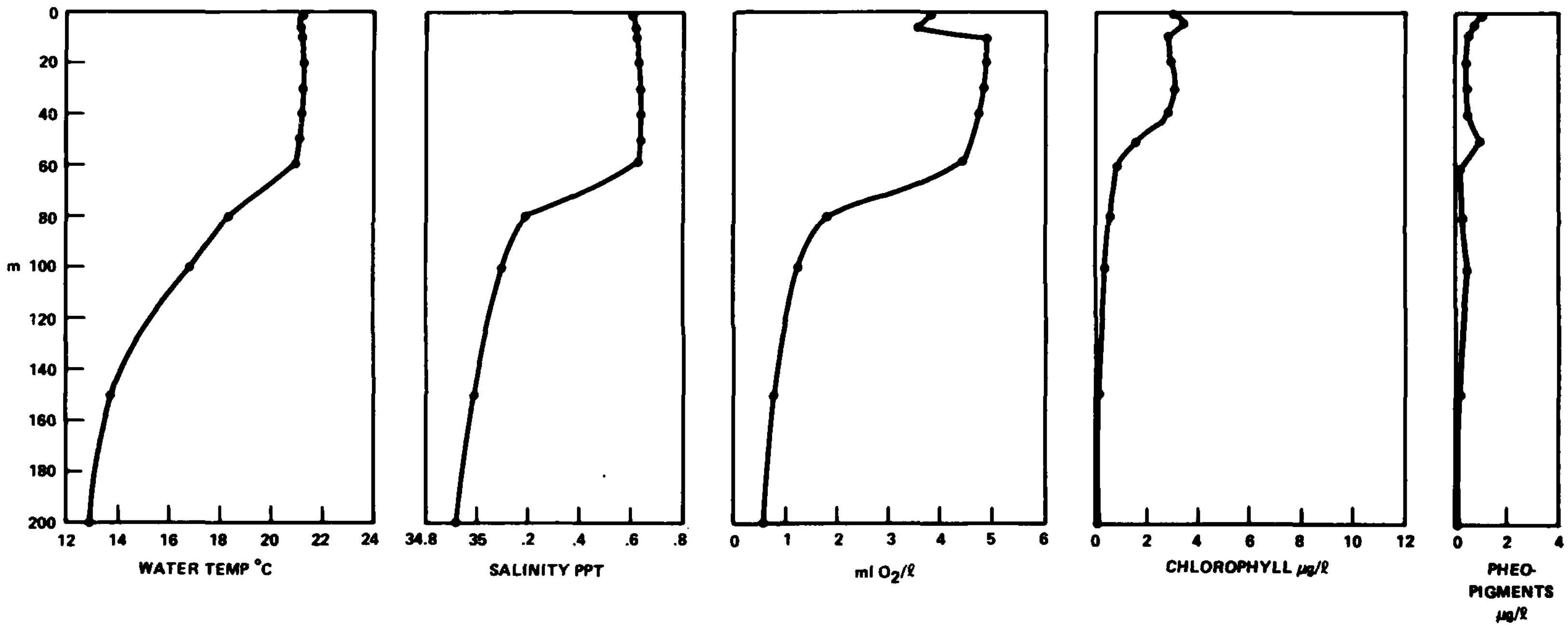
9/3/H,B VARIFRONT III LEG II 12/6/81

Figure F-7.



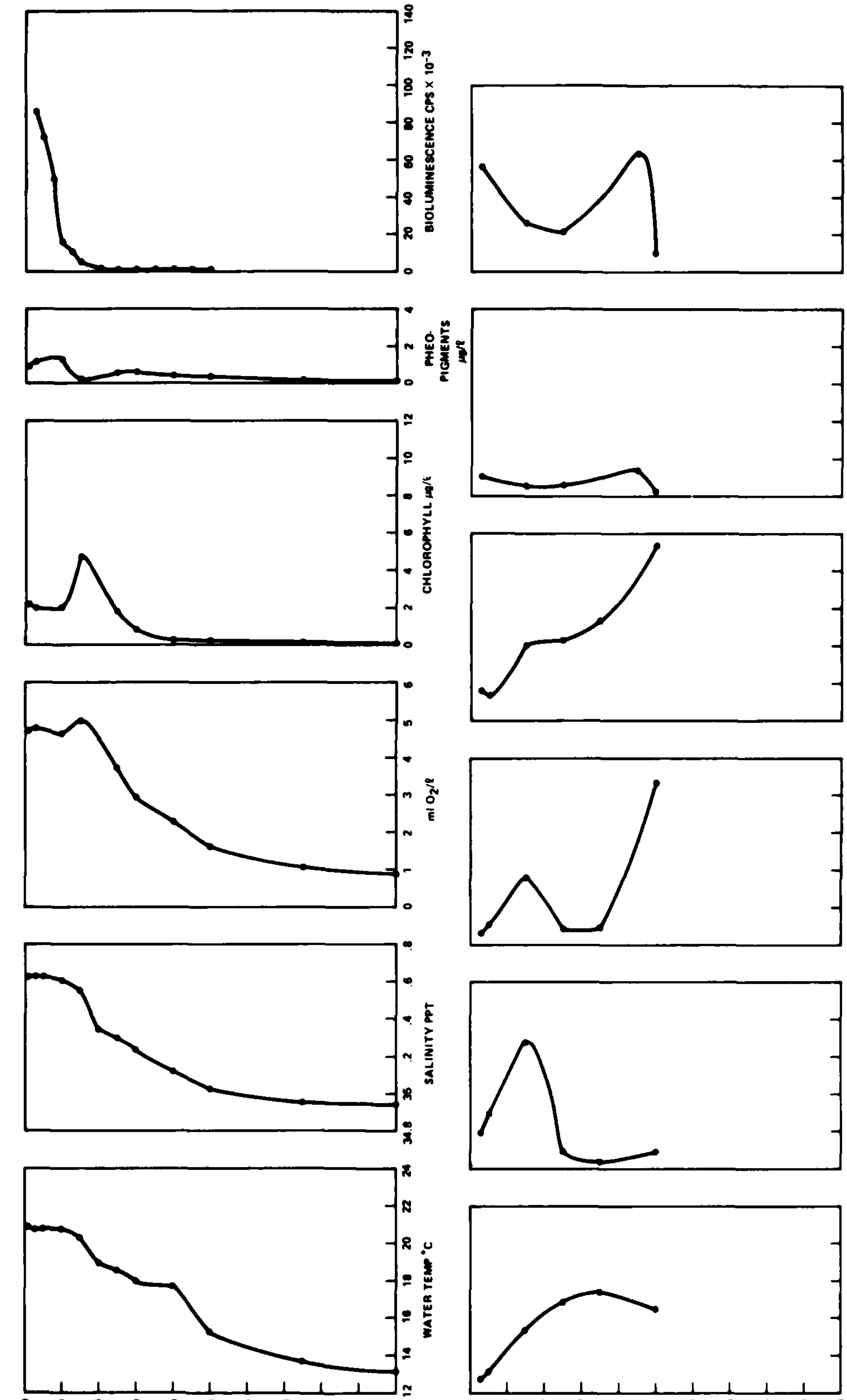
10/2/H,B VARIFRONT III LEG II 12/7/81

Figure F-8.



10/3/H VARIFRONT III LEG II 12/8/81

Figure F-9.



10/4/H,B VARIFRONT III LEG II 12/8/82

Figure F-10.

APPENDIX G
VERTICAL STATION DATA

Vertical station data for temperature, salinity, oxygen, chlorophyll *a*, phaeo-pigments, bioluminescence, nutrients, and particulate carbon and nitrogen are listed in tables G-1 to G-10. Details of the measurement techniques for station data are presented in the methods section of this report. Temperature and salinity data were derived from CTD casts. Samples for oxygen, chlorophyll *a*, and phaeo-pigment analyses were collected in conjunction with CTD casts using rosette-mounted Niskin bottles. A second cast using a submersible bathyphotometer was made to measure bioluminescence at most stations. Samples for nutrient analyses and for particulate carbon and nitrogen were collected from water pumped to the surface from the bathyphotometer. Printouts of data from the following stations are available:

Table	Station Number
G-1	6/1
G-2	8/1
G-3	8/2
G-4	8/3
G-5	9/1
G-6	9/2
G-7	9/3
G-9	10/3
G-10	10/4

Table G-1. Station 6/1/H&B.

Depth m	Water Temp. °C	Salinity PPT	O_2 ml/1	NO_3+NO_2 μm/1	NO_2 μm/1	NH_3 μm/1	PO_4 μm/1	Chlorophyll μg/1	Phaeo-pigments μg/1	Biolum photon/s/cc	N Total μg/1	C Total μg/1
5	23.483	35.206	4.23	.24	.04	.40	.62	.422	.184	2.94×10^8		
10	23.482	35.206	4.55	.19	.04	.37	.66	.816	.355	2.85×10^8	2.71	13.54
15	23.481	35.200								4.04×10^8		
20	23.481	35.207	5.28	.23	.05	.40	.77	.761	.325	7.74×10^8	4.05	
25	23.476	35.208								7.69×10^8		
30	22.992	35.147	4.19	.22	.04	.41	.84	.512	.379	5.86×10^8	2.89	11.14
35	22.276	35.097								6.54×10^8		
40	21.632	35.014	2.88	7.39	.55	.36	1.43	.552	.637	2.01×10^8	1.29	6.06
44	20.943	35.000								$.747 \times 10^8$		
50	19.640	34.929	1.85	14.80	.14	.33	2.01	.384	.312	$.305 \times 10^8$	0.95	4.73
60	17.358	34.898	1.30					.213	.098	$.134 \times 10^8$	0.72	3.05
63	17.247	34.902		17.63	.12	.68	2.38			$.098 \times 10^8$		
70	16.807	34.895										
80	16.311	34.906	1.23									
100	15.018	34.869	.99									
150	13.310	34.836	.23									
200	12.307	34.787										

Table G-2. Station 8/1/H&B.

Depth m	Water Temp. °C	Salinity PPT	O_2 ml/1	NO_3+NO_2 µm/1	NO_2 µm/1	NH_3 µm/1	PO_4 µm/1	Chlorophyll µg/1	Phaeo-pigments µg/1	Biolum photon/s/cc	N Total µg/1	C Total µg/1
1	18.310	35.271	4.35									
5	18.319	35.272	4.40	8.93	.43	.66	1.55	5.91	.40	2.30×10^9	6.85	
10	18.314	35.271	4.24	9.25	.44	.74	1.67	8.04	1.56	2.06×10^9	10.44	
15	18.306	35.270								1.21×10^9		
20	18.304	35.265	4.22	7.70	.35	.62	1.40	4.45	1.25	$.975 \times 10^9$	5.64	30.90
25	18.306	35.269								$.885 \times 10^9$		
30	18.291	35.267	3.91	10.53	.48	.81	1.79	4.42	1.28	$.724 \times 10^9$		
40	18.219	35.257	3.96	7.48	.31	.64	1.39	2.96	1.38	$.511 \times 10^9$	5.04	19.07
50	18.122	35.247	3.94	10.86	.40	.57	1.70	2.68	1.34	$.543 \times 10^9$	2.95	13.48
60	18.003	35.228	3.89	13.07	.48	.66	2.02	3.81	.61	$.514 \times 10^9$	3.72	21.28
70	17.952	35.224		12.90	.46	.70	2.10			$.382 \times 10^9$		
76	17.861	35.215		14.19	.52	1.58	2.51	2.57	.96		3.41	16.30
80	17.830	35.213	3.93							$.366 \times 10^9$		
95	17.384	35.186									0.62	3.10
100	17.216	35.168	2.73							$.212 \times 10^9$		
150	14.615	34.975	1.46									
200	13.184	34.892										

Table G-3. Station 8/3/H.

Depth m	Water Temp. °C	Salinity PPT	O_2 ml/1	NO_3+NO_2 µm/1	NO_2 µm/1	NH_3 µm/1	PO_4 µm/1	Chlorophyll µg/1	Phaeo-pigments µg/1	Biolum photon/s/cc	N Total µg/1	C Total µg/1
1	20.342	35.525	4.60									
5	20.336	35.526	4.62									
10	20.319	35.537	4.48									
20	20.313	35.544	4.49									
30	20.260	35.535	4.72									
40	19.957	35.460	4.39					3.78	.97			
50	18.118	35.158	1.40					3.94	.69			
60	17.025	35.109	1.66					3.54	.46			
80	16.387	35.069	1.44					3.38	.50			
100	15.054	35.007	1.32									
150	13.537	34.926	1.16									
200	12.505	34.844	.80									

Table G-4. Station 9/2/H.

Depth m	Water Temp. °C	Salinity PPT	O_2 ml/1	$NO_3 + NO_2$ µm/1	NO_2 µm/1	NH_3 µm/1	PO_4 µm/1	Chlorophyll µg/1	Phaeo-pigments µg/1	Biolum photon/s/cc	N Total µg/1	C Total µg/1
1	19.352	35.394	5.20									
5	19.330	35.406	4.85					4.96	1.89			
10	19.323	35.406	5.12					5.01	1.38			
20	19.055	35.350	4.45					4.25	1.23			
30	18.940	35.336	4.60					3.23	1.06			
40	18.861	35.335	3.68					3.18	1.25			
50	18.702	35.317	3.85					2.55	.78			
60	18.502	35.295	3.75					1.65	1.00			
80	16.410	35.103	2.18					.60	.65			
100	14.949	35.002	1.66					.41	.33			
150	13.712	34.928	1.15					.32	.16			
200	12.913	34.884	.98					.13	.24			

Table G-5. Station 9/1/H&B.

Depth m	Water Temp. °C	Salinity PPT	O_2 ml/1	NO_3+NO_2 µm/1	NO_2 µm/1	NH_3 µm/1	PO_4 µm/1	Chlorophyll µg/1	Phaeo-pigments µg/1	Biolum photon/s/cc	N Total µg/1	C Total µg/1
1			5.09					10.35	3.50			
5	19.849	35.441	5.11	5.29	.30	1.00	1.12	10.02	1.60	3.68×10^9	5.29	20.10
10	19.846	35.442	5.35	6.61	.37	.84	1.42	8.47	1.81	3.45×10^9	9.64	
15	19.837	35.445								3.16×10^9		
20	19.525	35.389	4.56					3.78	1.70	1.66×10^9		
25	19.304	35.377								1.48×10^9		
30	19.094	35.362	4.52					6.15	.44	1.27×10^9	5.63	26.30
40	19.001	35.352	4.70					3.34	2.01	0.767×10^9		
50	18.894	35.340	4.48	9.32	.55	.89	1.60	3.78	.79	0.909×10^9	3.47	32.18
60	18.866	35.339	4.40					2.91	1.47	0.369×10^9		
70	18.652	35.300		11.99	.54	.70	1.81			0.142×10^9		
80	18.374	35.287	4.00					2.15	.99	0.055×10^9		
90	17.908	35.241								0.027×10^9		
100	16.873	35.133	2.57	19.24	.08	.24	2.32	1.10	.82	0.027×10^9	1.07	4.42
150	14.044	34.935	1.42									
200	13.204	34.898										

Table G-6. Station 9/3/H&B.

Depth m	Water Temp. °C	Salinity PPT	O_2 ml/1	NO_3+NO_2 µm/1	NO_2 µm/1	NH_3 µm/1	PO_4 µm/1	Chlorophyll µg/1	Phaeo-pigments µg/1	Biolum photon/s/cc	N Total µg/1	C Total µg/1
1	19.781	35.443	4.86					4.10	1.20			
5	19.600	35.439	4.87	5.84	.39	.94	1.51	3.90	.62	4.06×10^9	5.54	
10	19.675	35.435	4.66	5.77	.39	.89	1.36	5.12	.45	3.75×10^9	3.92	13.60
15	19.433	35.394								3.48×10^9		
20	19.142	35.341	4.46					4.02	1.01	3.30×10^9		
25	18.725	35.299								2.91×10^9		
30	18.660	35.303	4.39	8.00	.50	.71	1.52			1.52×10^9	4.86	22.38
40	17.894	35.214	3.30					1.95	1.31	1.06×10^9		
50	17.311	35.172	2.68	15.81	.35	.23	2.07	1.17	.37	0.069×10^9	1.95	14.71
60	17.100	35.158	2.20					0.95	.52	0.068×10^9		
70	16.544	35.104		22.50	.06	.14	2.14			0.045×10^9	1.33	5.76
80	15.334	35.029						.16	.36	0.017×10^9		
90	15.237	35.023										
92	15.195	35.022								0.018×10^9		
100	14.743	34.991	1.26	20.86	.07	.19	2.50	.13	.19	0.020×10^9	1.36	6.66
150	13.296	34.902	1.07					.09	.23			
200	12.820	34.880	.99									

Table G-7. Station 8/2/H&B.

Depth m	Water Temp. °C	Salinity PPT	O_2 ml/1	NO_3+NO_2 µm/1	NO_2 µm/1	NH_3 µm/1	PO_4 µm/1	Chlorophyll µg/1	Phaeo-pigments µg/1	Biolum photon/s/cc	N Total µg/1	C Total µg/1
1			4.62					7.76	.83			
3	20.714	35.519								1.80×10^9		
5	20.745	35.518	5.06	1.49	.08	.24	.63	9.07	1.17	1.82×10^9	9.70	
10	20.676	35.514	4.50	1.96	.15	.28	.52	9.67	.32	1.78×10^9	22.64	
15	20.482	35.504								1.60×10^9		
20	20.448	35.505	4.45							0.983×10^9		
25	20.307	35.483						6.05	1.86	0.812×10^9		
30	30.287	35.481		4.91	.23	.27	1.11			0.698×10^9	15.04	
40	19.969	35.422	4.37					4.49	1.54	0.415×10^9		
50	19.226	35.333	3.63	7.72	.33	.34	1.31	3.62	1.32	0.366×10^9	7.60	
60	18.754	35.297	2.80							0.289×10^9		8.78
70	17.944	35.218		14.84	.50	.51	2.00			0.193×10^9	3.45	16.80
75	17.544	35.179						2.07	1.62			
80	17.240	35.161								0.059×10^9		
90	16.671	35.114								0.025×10^9		
95	16.406	35.102		15.61	.20	.51	2.03			0.024×10^9		
100	16.287	35.089										
150	13.753	34.913	1.12					.59	.39			
200	12.975	34.878	.82					.41	.22			

Table G-8. Station 10/3/H.

Depth m	Water Temp. °C	Salinity PPT	O_2 ml/1	$NO_3 + NO_2$ µm/1	NO_2 µm/1	NH_3 µm/1	PO_4 µm/1	Chlorophyll µg/1	Phaeo-pigments µg/1	Biolum photon/s/cc	N Total µg/1	C Total µg/1
1	21.085	35.624	3.81					3.23	.88			
5	21.094	35.628	3.60					3.36	.72			
10	21.092	35.626	4.89					2.83	.45			
20	21.091	35.628	4.89					2.99	.48			
30	21.096	35.629	4.83					3.07	.58			
40	21.092	35.628	4.77					2.77	.53			
50	21.045	35.641	4.66					1.42	.87			
60	20.978	35.625	4.43					.83	.13			
80	18.167	35.186	1.82					.47	.26			
100	16.777	35.101	1.25					.16	.23			
150	13.665	34.975	.78					.05	.16			
200	12.948	34.919	.65					.04	.10			

Table G-9. Station 10/2/H&B.

Depth m	Water Temp. °C	Salinity PPT	O_2 ml/1	$NO_3 + NO_2$ µm/1	NO_2 µm/1	NH_3 µm/1	PO_4 µm/1	Chlorophyll µg/1	Phaeo-pigments µg/1	Biolum photon/s/cc	N Total µg/1	C Total µg/1
1	21.280	35.620	4.78					2.07	.89			
5	21.227	35.621	4.79	5.05	.64	.33	1.26	2.05	1.06	2.45×10^7	4.12	17.51
10	21.211	35.623	4.79	4.92	.60	.28	1.26	2.56	1.05	1.53×10^7	2.93	11.27
15	21.186	35.626								1.98×10^7		
20	21.098	35.626	4.74					3.78	1.89	2.27×10^7		
25	21.064	35.629								3.41×10^7		
30	21.005	35.626	4.55	8.24	.29	.25	1.45	2.03	.96	3.99×10^7	0.41	2.37
40	20.854	35.622								3.15×10^7		
50	20.665	35.601	4.27	13.63	.07	.30	2.07	1.50	.61	1.40×10^7	0.11	3.16
60	20.402	35.600	4.53					.88	.79	0.658×10^7		
70	19.877	35.507		14.81	.02	.20	2.24			0.513×10^7		
80	17.997	35.177	1.48					.13	.15	0.350×10^7		
90	17.350	35.140								0.265×10^7		
97	16.330	35.063										
100	16.193	35.064	1.27	16.41	.02	.22	2.50	.14	.23	0.280×10^7		
150	13.038	34.932	1.33					.12	.24			
162	12.981	34.929	.83					.05	.25			
200												

Table G-10. Station 10/4/H&B.

Depth m	Water Temp. °C	Salinity PPT	O_2 ml/1	$NO_3 + NO_2$ µm/1	NO_2 µm/1	NH_3 µm/1	PO_4 µm/1	Chlorophyll µg/1	Phaeo-pigments µg/1	Biolum photon/ s/cc	N Total µg/1	C Total µg/1
1	20.854	35.624	4.74					2.21	.90			
5	20.846	35.625	4.79	2.00	.19	.19	.89	2.01	1.10	2.17×10^9	2.83	15.39
10	20.848	35.624		28.81	.30	.29	.83			1.84×10^9		
15	20.845	35.615								1.21×10^9		
20	20.751	35.615	4.66					1.97	1.41	0.371×10^9		
25	20.574	35.600								0.281×10^9		
30	20.358	35.559	5.06	8.34	.69	.64	1.49	4.89	.23	0.139×10^9	1.28	6.43
35	20.040	35.505								0.082×10^9		
40	18.928	35.338								0.048×10^9		
50	18.610	35.296	3.72	12.22	.09	.21	1.53	1.79	.56	0.032×10^9	1.71	4.94
60	17.973	35.226	2.93					.79	.58	0.018×10^9		
70	17.460	35.165		13.68	.04	.21	1.82			0.017×10^9		
80	16.708	35.122	2.27					.25	.43	0.013×10^9		
90	16.031	35.081								0.0058×10^9	3.83	17.10
100	15.225	35.013	1.62	11.25	.07	1.38	2.82	.23	.35	0.0052×10^9	0.46	2.13
150	13.645	34.947	1.02					.14	.13			
200	13.096	34.937	0.88					.06	.12			

APPENDIX H
PRIMARY PRODUCTIVITY MEASUREMENTS

Primary productivity determined by uptake of radioactive carbon-14 is presented in table H-1.

Table H-1. Primary productivity measurements.

Station 8/1/P

Depth	Light Percent	mg C/m^3/hr
0	100	12.12(15.49)
4.0	50	15.58(14.84)
8.0	25	11.69(14.74)
13.0	10	4.49(3.72)
25.0	1	1.23(1.14)

Station 8/3/P

Depth	Light Percent	mg C/m^3/hr
0.0	100	12.67(15.14)
4.0	50	13.04(− −)
7.0	25	14.44(11.73)
12.0	10	3.10(4.35)
25.0	1	2.34(2.04)

Station 9/2/P

Depth	Light Percent	mg C/m^3/hr
0.0	100	2.83(3.43)
4.0	50	14.94(14.78)
8.0	25	11.80(11.08)
13.0	10	3.52(9.61)
26.0	1	3.05(2.80)

Station 10/1/P

Depth	Light Percent	mg C/m^3/hr
0.0	100	5.72(5.69)
5.0	50	14.31(14.76)
10.0	25	9.90(12.22)
16.0	10	1.36(2.53)
31.0	1	1.08(0.59)

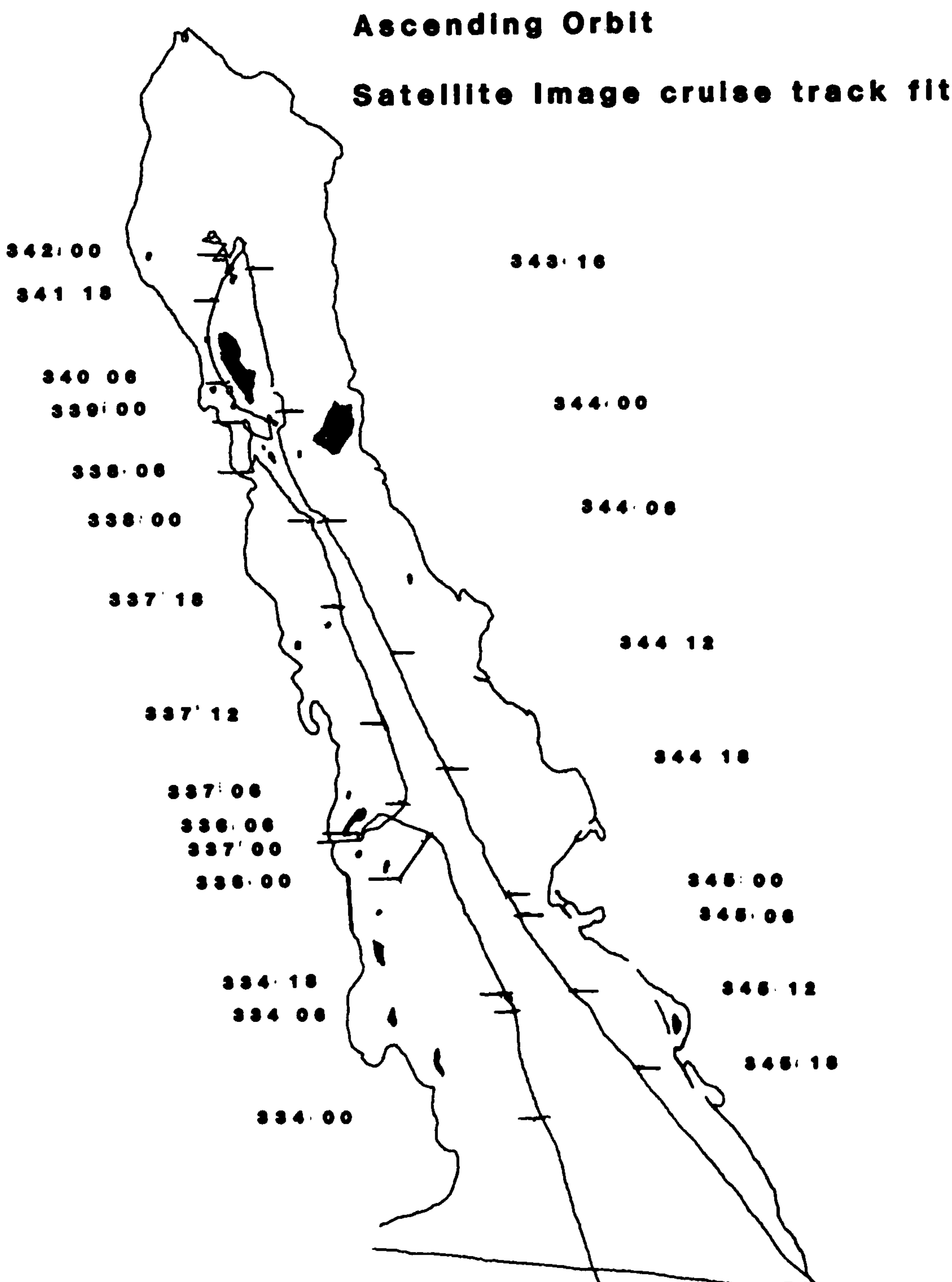
Station 10/3/P

Depth	Light Percent	mg C/m^3/hr
0.0	100	2.51(3.48)
4.0	50	9.94(7.83)
7.0	25	4.80(5.60)
11.0	10	4.24(3.42)
22.0	1	0.94(1.45)

APPENDIX I
SATELLITE IMAGERY

NOAA 6 and NOAA 7 infrared satellite imagery was collected and processed by the National Earth Satellite Service (NESS), Redwood City, California. Cloud-free imagery collected during the operation was suitably enhanced and enlarged. In all images, progressively higher temperatures are shown as progressively darker areas. Images are designated according to whether the satellite was in an ascending (A) or descending (D) orbit. Using a projection technique, Larry Breaker of NESS (Redwood City) produced overlays of the ship's cruise track for both ascending and descending orbits. These overlays, presented as figures I-1 and I-2, can be used to locate the position of the ship relative to thermal features visible in the imagery. The position of the ship along the cruise track is indexed with tick marks and the corresponding Julian day/GMT hour in the margin of each overlay. Each image is referenced by the time the image was captured (Julian day/GMT hour). The following imagery is available:

Figure Number	Capture Time	A or D Orbit
I-3	311/1010	D
I-4	317/1517	D
I-5	318/1030	D
I-6	328/1014	D
I-7	334/2205	A
I-8	335/1034	D
I-9	335/2154	A
I-10	339/0246	A
I-11	339/0948	D
I-12	341/1603	D
I-13	342/0316	A
I-14	343/1517	A
I-15	334/2200	D
I-16	344/1030	D
I-17	344/1452	A
I-18	344/2149	A
I-19	345/1019	D
I-20	346/1007	D
I-21	346/2126	A
I-22	347/0300	A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Satellite image cruise track fit
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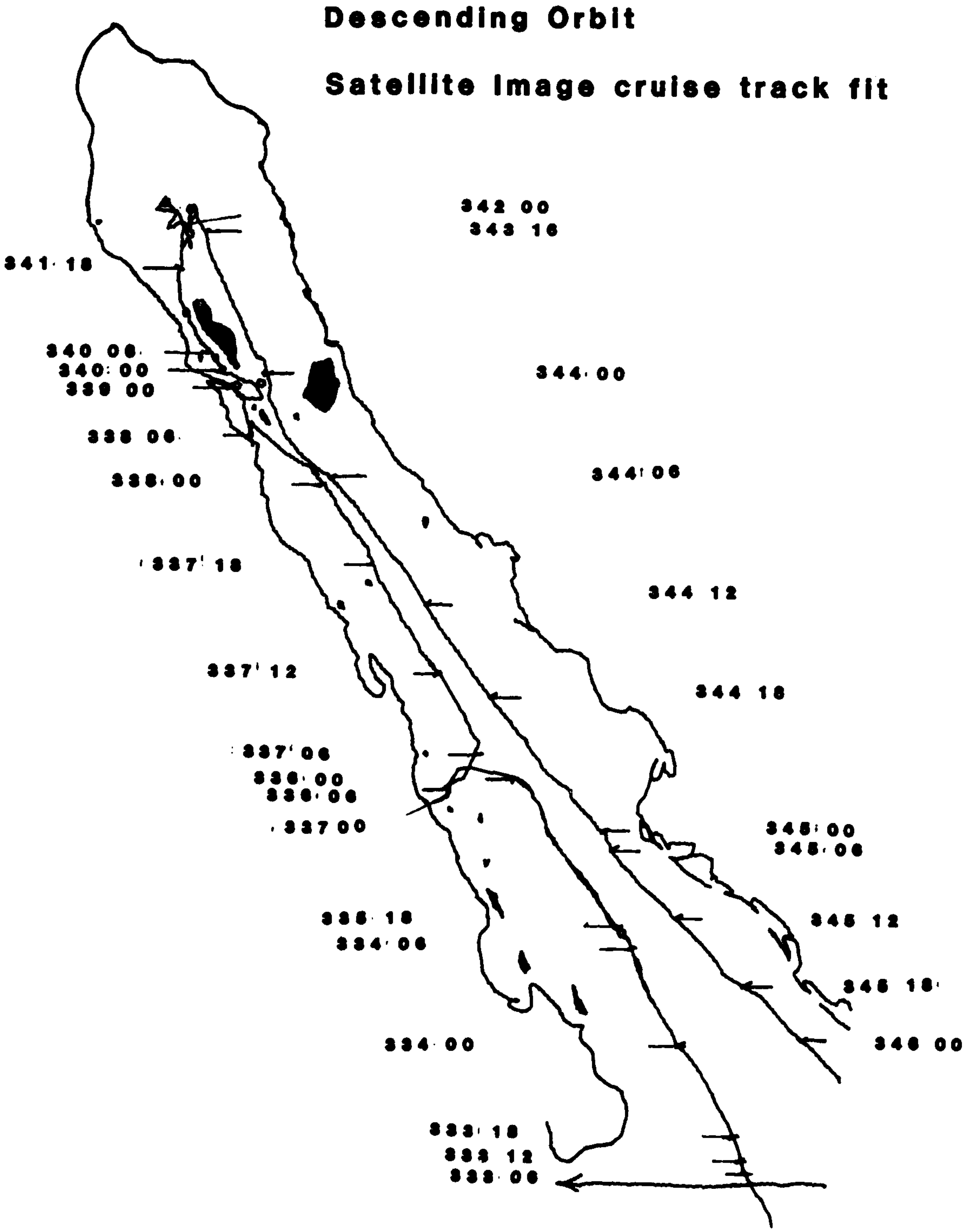
Figure I-1.


Descending Orbit
Satellite image cruise track fit
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337 00
335 18
334 06
334 00
333 18
333 12
333 06
344 00
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Figure I-2.

Figure I-3.

Figure I-4.

Figure I-5.

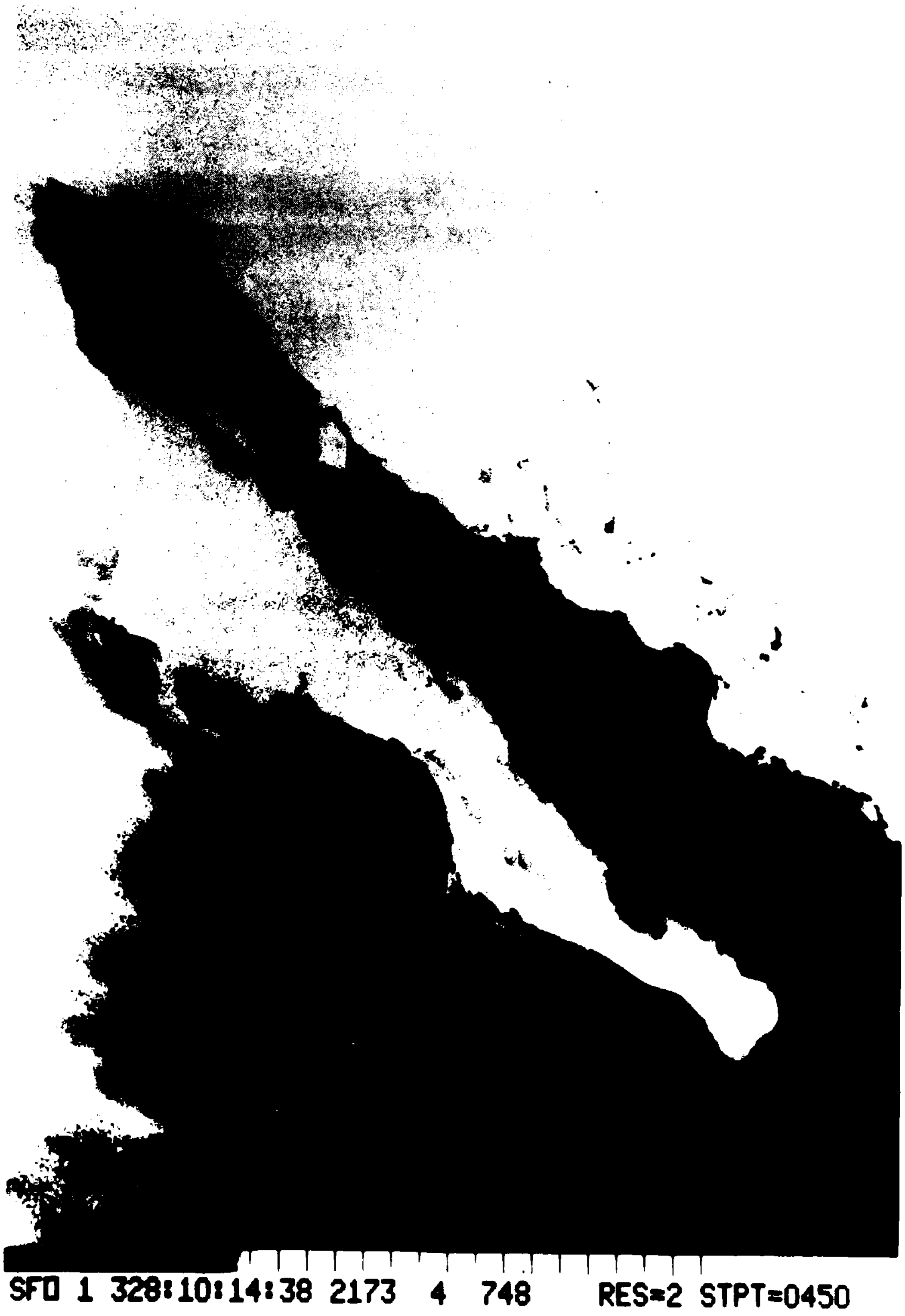


Figure I-6.

Figure I-7.

Figure I-8.

Figure I-9.

Figure 1-10.

Figure I-11.

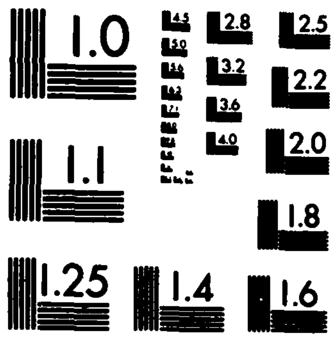
Figure I-12.

SFO 1 342:03:16:55 12721 4 [illegible]

Figure [illegible]

AD-A185 011 VARIFRONT III EXPEDITION DATA REPORT (USNS DE STEIGUER CRUISE 1202-82) BI..(U) NAVAL OCEAN SYSTEMS CENTER SAN DIEGO CA S H LIEBERMAN ET AL. OCT 86 NOSC/TD-992 2/2

UNCLASSIFIED F/G 8/3 NL



MICROCOPY RESOLUTION TEST CHART
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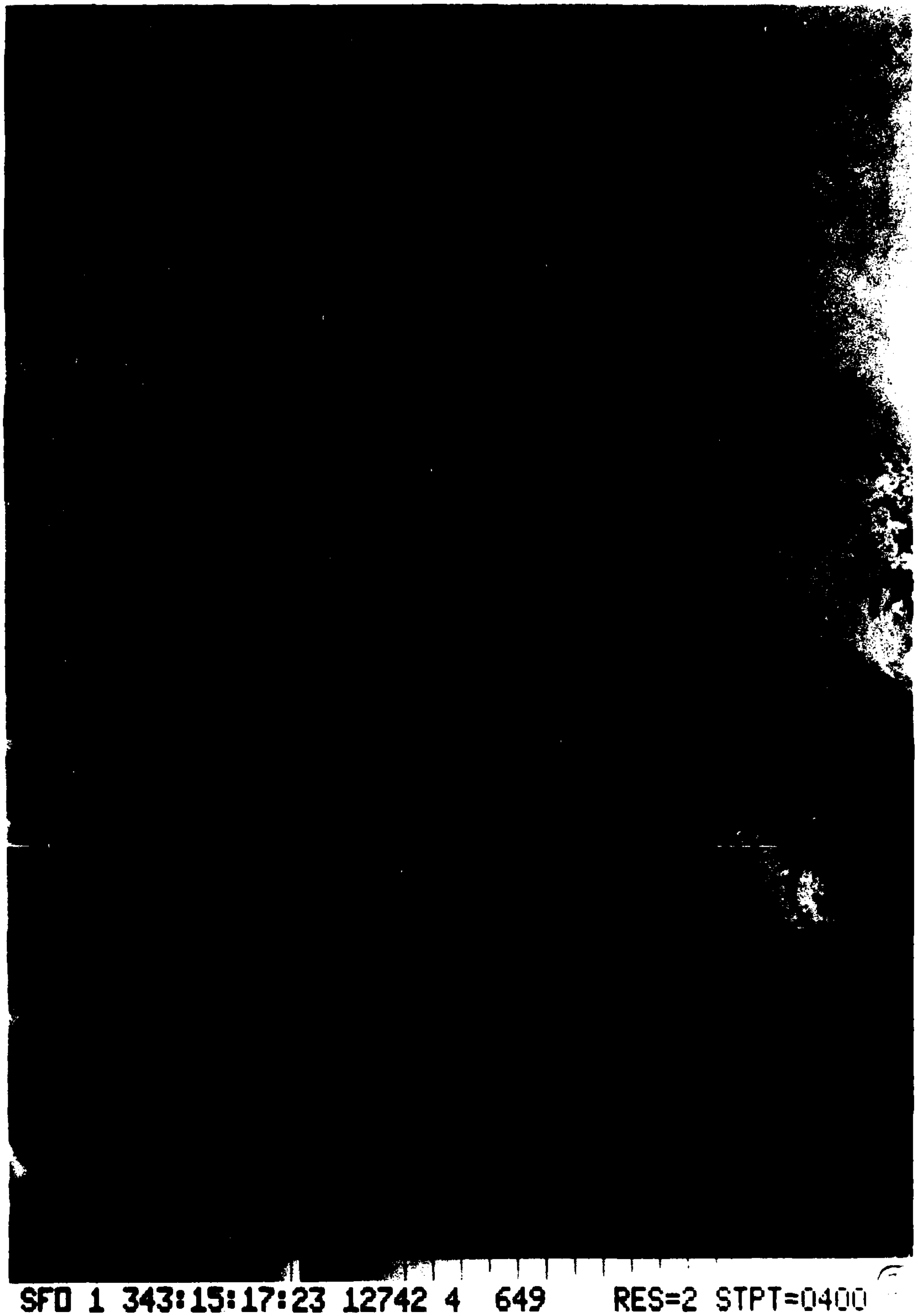

Figure I-14.

SFD 1 343:22:00:15 2392 4 748 RES=2 STPT=0110 (A)

Figure I-15.

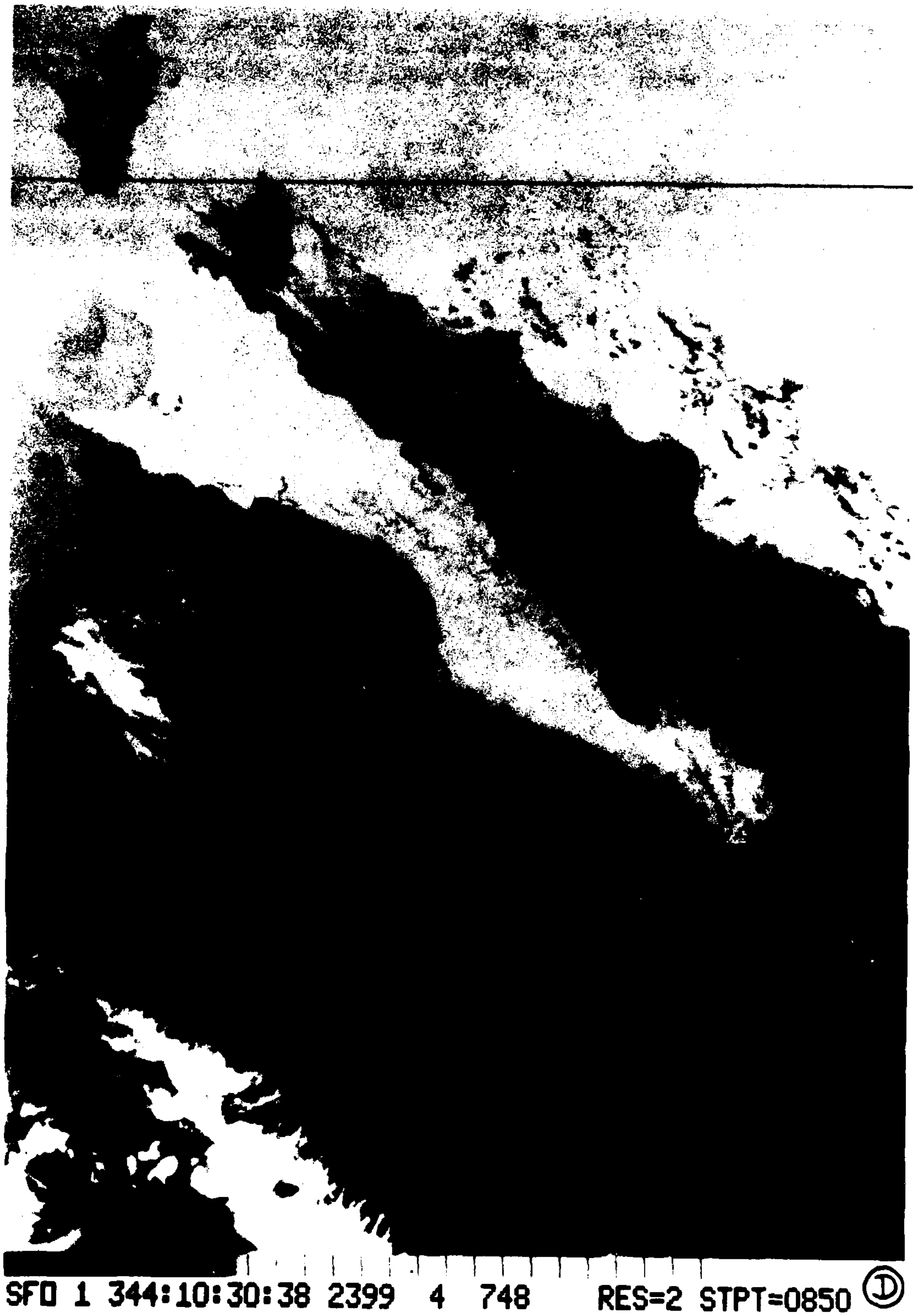

Figure I-16.

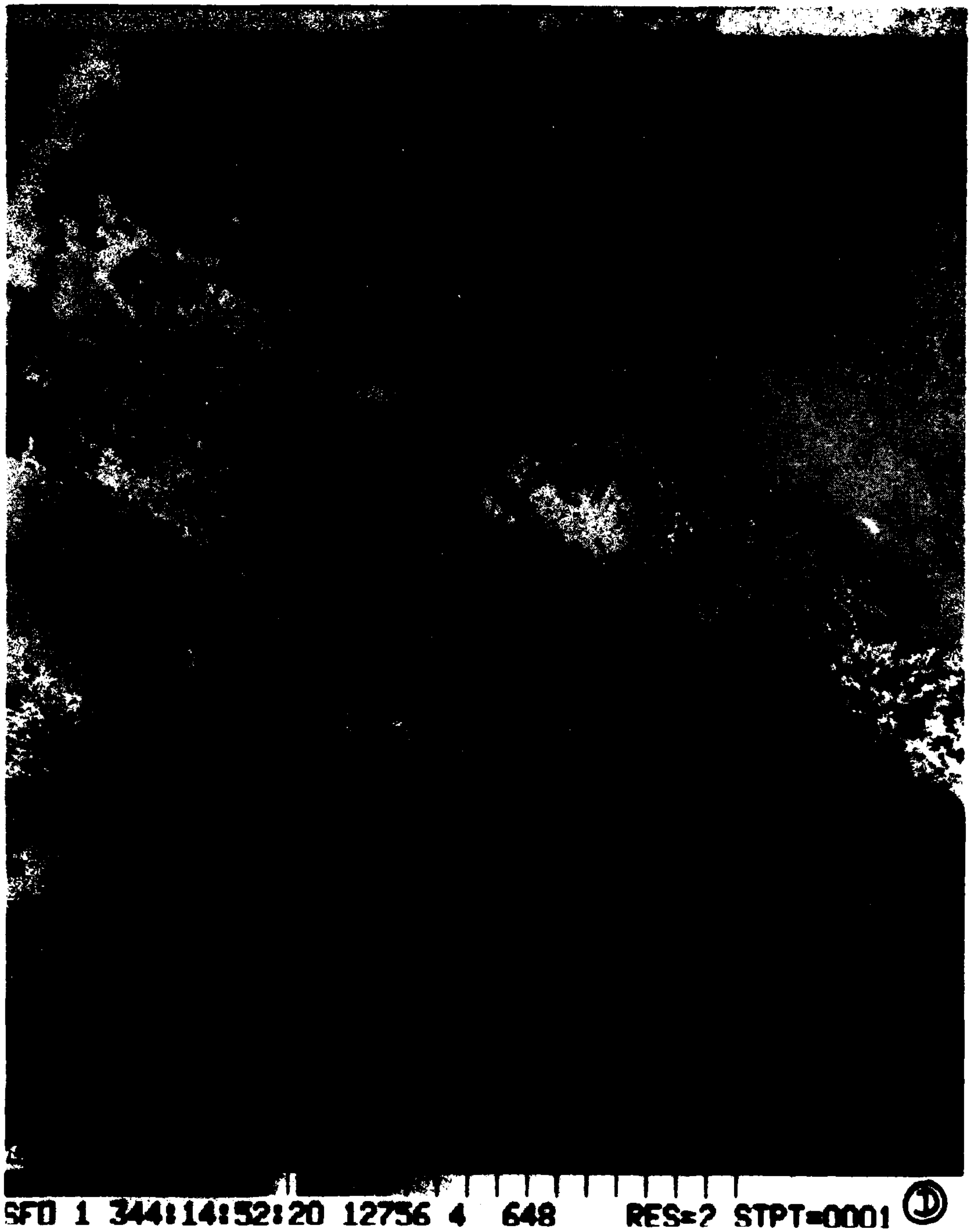

Figure I-17.

Figure I-18.

Figure I-19.

Figure I-20.

Figure I-21.

Figure I-22.

END

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